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U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN NO. 143.

A. C. TRUE, Director.

STUDIES

ON THE

DIGESTIBILITY AND NUTRITIVE VALUE OF BREAD

AT THE

MAINE AGRICULTURAL EXPERIMENT STATION

1899-1903.

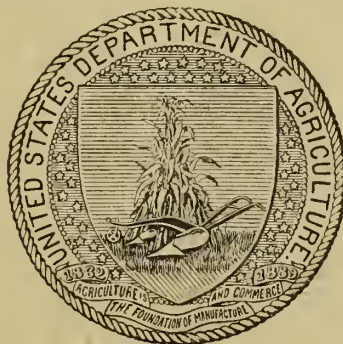
BY

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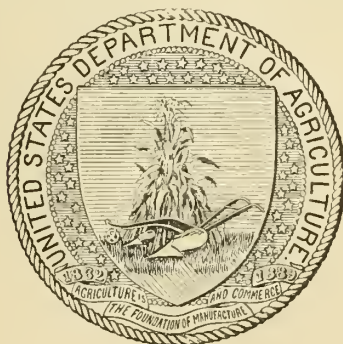
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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., February 15, 1904.

SIR: I have the honor to transmit herewith and to recommend for publication as a bulletin of this Office a report of investigations on the digestibility and nutritive value of bread and on methods of separating feces in digestion experiments with man, carried on at the Maine Agricultural Experiment Station in 1899-1903, by Charles D. Woods, director, and L. H. Merrill, chemist of the station. The studies were conducted under the immediate supervision of Prof. W. O. Atwater, chief of nutrition investigations, and form a part of the investigations on the food of man conducted under the auspices of this Office.

The results of the digestion experiments with bread made from different sorts of flour ground from the same lots of wheat are in accord with those obtained in earlier investigations of this series, and show that breads made from all the common grades of flour are quite thoroughly digested and differ little in nutritive value. They also emphasize the fact that breads of all sorts are among the most useful and economical articles of diet.

Respectfully,

A. C. TRUE,
Director.

HON. JAMES WILSON,
Secretary of Agriculture.

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THE DIGESTIBILITY AND NUTRITIVE VALUE OF BREAD.

INTRODUCTION.

The grade of wheat flour most commonly used in making white bread is known as straight or standard patent. In the production of this flour by the modern process of milling, the bran and aleurone layers and the germ are removed by preliminary treatment and the remainder of the kernel is then ground. The bran is left out because if included it would make the flour coarse, and the germ is removed because it contains the oil of the wheat, which is likely to become rancid and spoil the flour, and which acts upon the other constituents of the flour so that the bread in baking is darkened in color.

Both the aleurone layer, or inner portion of the bran, and the germ are rich in nitrogenous matter and mineral salts, and the germ is also much richer in fats than the other portions of the wheat kernel; hence it is frequently claimed that the white flours are overrefined, that the valuable parts of the wheat are left in the waste products, and that the fine grades of patent flour consist of little else than starch. The coarser grades of flour on the market, the so-called Graham flours, are milled in accordance with the idea of avoiding the apparent waste occurring in the production of the finer flours. In milling Graham flour the whole of the wheat kernel is ground and no bolting or sorting process is employed, the resulting product being in reality wheat meal.

It was found, however, that the presence of so large a proportion of the bran as there is in flour of this description seemed in many cases to result in an irritation of the delicate mucous lining of the intestine. As a compromise between the coarse Graham and the fine white flours an intermediate product was placed upon the market, to which the name "whole wheat" or "entire wheat" was given. The manufacturers of this flour claim that it is prepared by removing only the woody part of the bran, leaving the aleurone layer and the germ, and that it therefore contains all the nutritious part of the wheat kernel without the irritating bran. As a matter of fact, the attempts to remove only the bran do not seem in all cases to have been entirely

successful, as the appearance of the flour often shows that part of the coarse material still remains in the flour.

From the standpoint of average chemical composition the flours containing the whole of the wheat kernel would appear to be more nutritious than those from which the bran and germ have been removed. A comparison of the figures for the composition of the different grades of flour, given in Table 1, shows somewhat larger proportions of protein and fat in the coarser flours. Disregarding the fact that all grades of flour contain large proportions of starch, which is a valuable nutrient, the advocates of the coarse flours appear to assume that their nutritive value is directly proportional to the amount of nitrogenous matters which they contain, believing, apparently, that all the nitrogenous compounds of the wheat are of equal food value. But there are reasons for thinking that this may not be the case. It is certain that the various compounds in that part of the wheat kernel which predominates in the white flours are not identical with those of the bran or the aleurone layer, and it is believed they differ from them in nutritive value.

The actual test of nutritive value, however, is not the quantity of nutritive ingredients contained in the flours, but the proportions that may be digested and absorbed from them, as only material that can be digested can serve the body for nourishment. A considerable amount of investigation of the digestibility and nutritive value of different grades of wheat flour has been carried on in Europe, with very interesting and valuable results, but few of these are applicable to the conditions common in this country, because the flours used were somewhat different from those which are common here, and the breads were made by methods not ordinarily followed by our bakers. Furthermore, the experiments have been conducted generally in such ways that it is not possible to make strict comparison of the results so as to show the relative nutritive values of the different grades of flour. In order to permit of reliable comparison the different flours should be ground from the same lot of wheat, because of variations in the composition of wheats from different sources, whereas generally the European investigations of this character were made with flours purchased in the open market.

In connection with the nutrition investigations carried on under the auspices of the Office of Experiment Stations, during the past few years studies of the digestibility and nutritive value of bread made from different grades of flour ground from the same lots of wheat have been made at the Maine and Minnesota experiment stations for the purpose of accumulating data which will serve in answering questions regarding the effects of different methods of milling upon the nutritive value of flour. The experiments described in the following

pages, which were conducted at the Maine Experiment Station during the years 1899-1902, were in continuation of those reported by the same authors in a previous bulletin^a of this series.

The investigations reported in the present bulletin comprise experiments with men on the digestibility of bread from different grades of flour, including determinations of the income and outgo of nitrogen; artificial digestion tests with pepsin solution of all the breads used in the experiments with men; estimation of the amounts of metabolic nitrogen in the feces obtained in the experiments; and a study of methods of marking and separating feces in digestion experiments. The details of the work carried out along these lines are given in the sections that follow.

EXPERIMENTS ON THE DIGESTIBILITY OF BREAD.

Thirty-two digestion experiments with men were completed. They were divided into three series, in each of which three men served as subjects. Three kinds of flour—Graham, entire wheat, and standard patent—were used in both the first and the second series, all three grades in each series being ground from the same lot of wheat; though the lot used in the second series was different from that in the first. In the third series still another lot of wheat was used. In this case, however, the experiments with Graham flour were not completed, because the flour did not appear to be true to name, as explained later.

The first series, comprising experiments Nos. 431-441, was similar to those previously reported;^a that is, the diet contained a relatively large amount of bread eaten with few other materials, which were of such a nature that their digestibility could be assumed for the conditions of the experiment, and the digestibility of the bread alone could therefore be calculated. The last two of the 11 experiments in this series differed from the others in that the diet was much smaller, having been designated "half ration," the purpose being to compare the digestibility of rations of different size. Experiments Nos. 431-433 were similar tests with three subjects in which bread from white flour formed the main part of the diet; Nos. 434-436 were like the former, except that entire-wheat bread was used; and Nos. 437-439 were similar, but with Graham bread. Experiments Nos. 440 and 441 were like Nos. 431-433, but the ration was reduced to one-half the usual amount.

In the second series, comprising experiments Nos. 442-450, and the third series, Nos. 451-462, the ration was a simple mixed diet in which the number of food materials other than bread was larger, and the amount of bread, though large, was smaller in proportion to the

^a U. S. Dept. Agr., Office of Experiment Stations Bul. 85.

total ration than was the case in experiments Nos. 431-441. The purpose in the later experiments was to determine the effect of the different kinds of bread upon the digestibility of an ordinary mixed diet as a whole rather than to estimate the digestibility of the bread alone. Of the experiments in the second series, Nos. 442-444 were three with a mixed diet, in which about a half of the total protein was furnished by white bread; Nos. 445-447 were similar but with entire-wheat bread, and Nos. 448-450, three others of the same kind, with Graham bread in place of the white bread. In the third series, Nos. 451-453 were similar to Nos. 442-444 of the second series, but with entire-wheat bread, and Nos. 454-456 were similar experiments with white bread; likewise Nos. 457-459 were with entire-wheat bread and Nos. 460-462 with white bread.

DESCRIPTION OF FLOURS.

The flours used in these experiments, which were furnished by Prof. Harry Snyder, of the Minnesota Experiment Station, were ground from the same lots of wheat, at the same time and in the same mill as those used in digestion experiments made by him and reported in earlier bulletins^a of this Office. The numbers of the flours in the following description of samples are the same as those in the table of composition on page 14.

Nos. 6133 and 6443 were straight or standard patent flours from the best quality of hard spring wheat grown in the Northwest, milled in the same way as the bread flour most commonly found in the market. This grade of flour consists of the first and second patents and the first clear grade. About 72 pounds of straight patent flour is obtained from 100 pounds of screened and cleaned wheat such as was used in these experiments. These two samples were from different lots of wheat. The former was used in experiments Nos. 431-433 and the latter in Nos. 442-444.

Nos. 6142 and 6444 were so-called entire-wheat or natural flours, which are obtained by removing a portion of the bran and grinding the remainder of the wheat kernel. They are of a coarser texture than the patent grades. About 85 pounds of entire-wheat flour is milled from 100 pounds of cleaned wheat. These two samples were from the same lots of wheat as Nos. 6133 and 6443, respectively. No. 6142 was used in experiments Nos. 434-436 and No. 6444 in Nos. 445-447.

Nos. 6155 and 6442 were Graham flours, or wheat meals, produced by grinding the whole of the wheat kernel, bran and all. The presence of the bran prevents fine pulverization; and since in the manufacture of true Graham flours no sieves or bolting cloths are employed, the flour contains many coarse particles. No. 6155 was from the same

^a U. S. Dept. Agr., Office of Experiment Stations Buls. 101 and 126.

lot of wheat as Nos. 6133 and 6142, and No. 6442 was from the same lot as Nos. 6443 and 6444. These two samples of Graham flour were used in experiments Nos. 437-439 and 448-450, respectively.

No. 6597 was a white flour, not strictly a straight grade, but more properly called a blend. It consisted largely of straight grade, but with a little of the lower grades and the germ included. This sample was used in experiments Nos. 454-456 and Nos. 450-462.

No. 6598 was an entire-wheat flour from the same lot of wheat as No. 6597. It was used in experiments Nos. 451-453 and Nos. 457-459.

PREPARATION OF THE FOOD.

All the breads consumed in the experiments here reported were specially prepared from the flours described above. For the first series of experiments, Nos. 431-441, the breads were made with yeast and the ingredients were not weighed. In the later work baking powder was used, and all the constituents were weighed in order to secure greater uniformity of composition. In the second series, experiments Nos. 442-450, the bread was made according to the following formula: Flour, 450 grams; salt, 8 grams; sugar, 30 grams; baking powder, 12 grams, and whole milk, 375 grams. To this enough water was added to give the dough the right consistency. The baking was done in an Aladdin oven over a solid-flame gas burner. The temperature was carefully regulated and the resulting breads were of very uniform character. The breads used in the third series, experiments Nos. 451-462, were made in the same way except that water was used instead of the whole milk.

The meat used in all but three of the second and all of the third series of experiments was prepared from shoulder clod of beef, slightly corned. The bone, fat, and connective tissues were removed from the cooked meat as completely as possible and the meat ground in a meat cutter. After thorough mixing, the meat was placed in glass fruit jars, enough in each to serve for a single meal, the covers loosely adjusted, and the jars immersed nearly to the shoulder in a large kettle of water, which was gradually heated to the boiling point. After the heating had been continued for thirty minutes, the covers were firmly screwed down and the jars removed, cooled, and stored in a refrigerator, though this last was probably a needless precaution. To insure sterilization, on two succeeding days the covers were loosened and the jars again heated for thirty minutes at 100° C. Enough meat was thus prepared to last through an experiment, or in one case through two experiments of four days each. When a jar was opened, the entire contents were removed and thoroughly mixed, since the juices separated more or less from the meat during the sterilizing process. The portion for each subject was weighed in a porcelain dish and warmed.

One of the well-known brands of canned boned chicken was also found to be admirably adapted to the purpose of the experiments. The contents of several cans were passed through a meat cutter and thoroughly mixed. Thus prepared the material was placed in glass fruit jars, about 250 grams to the jar, and sterilized in the manner described above. The amount in one jar was sufficient for a supper for three subjects, 75 grams being allowed for each man, leaving a margin for samples. The chicken was compressed into cakes in a mold constructed for the purpose and served cold.

A sufficient amount of potatoes for a day's use was boiled on the day preceding each experimental day. These were prepared in different ways as required, some being sliced and fried for breakfast and the rest mashed, seasoned, and warmed for dinner.

In experiments Nos. 431-441 only the crumb of the bread was eaten. Bread was prepared for each meal by cutting the loaf in thin, uniform slices, removing the crust from each, and placing the slices in four piles in rotation, one being reserved for each man and the fourth set aside and prepared for analysis as described below. In the later experiments (Nos. 442-462) the crust was not removed. A loaf was selected for each man and exactly one-fourth by weight removed for analysis. The reserved portion was thinly sliced and dried at a temperature of about 50° C. After three or four days the samples were removed from the drying ovens, allowed to stand for several days exposed to the open air of the laboratory, and then finely ground in a hand mill.

When beef or chicken was served, 25 grams were set aside for analysis and dried at 50° C. Samples of 100 grams each were taken from the potatoes morning and night. In each case the small samples of beef, chicken, or potatoes were combined into a composite sample, thus necessitating but one analysis of each kind of food for an experiment of three days.

SEPARATION OF FECES.

Each experiment of the first series, Nos. 431-441, began with a supper of milk with which was taken a gelatin capsule filled with lampblack. During the two days following, the experimental diet (which consisted largely of the bread studied) was eaten, and the experiment then terminated with a breakfast similar to the preparatory supper, consisting of milk with a capsule of lampblack. Each experimental period, therefore, included eight meals—an initial and closing meal, yielding feces of an unusual and marked character, and two full days of three meals each, constituting the experiment proper, yielding feces of the usual character. In the examination of the feces those portions were rejected which were strongly colored with lampblack. That portion appearing between these two "markers" was assumed to be derived

from the food studied, and was collected, dried, weighed, sampled, and analyzed. The accuracy of the digestion experiments, as is always the case, was largely dependent upon the exactness with which the separation of the feces could be accomplished; no refinements of methods of analysis can atone for failure to achieve this. It is believed that in the work here reported the separations were tolerably exact, although in a few instances the line of demarcation was less sharp than was desirable. This matter is discussed at some length on pages 68-77.

In the second and third series, experiments Nos. 442-462, the preliminary supper and supplementary breakfast of milk were omitted. The lampblack used for marking the feces was inclosed in gelatin capsules coated with shellac, one of which was taken at breakfast on the first day of the experiment and another with the breakfast next following the last day of the experiment proper. In this case, therefore, the feces of the experiment included all that excreted from the time the lampblack first appeared until the appearance of the second lampblack.

COLLECTION OF URINE.

The urine was collected during each of the experiments, beginning with the time of the first meal and ending at the same time on the day following the last one of the experiment. As previously noted,^a these periods were not chosen in the belief that the nitrogen of urine thus collected represented the protein katabolism of the food studied, but because in the absence of any means of marking the urine, and the lack of definite information concerning nitrogen lag, i. e., the time between the ingestion of nitrogen in the food and its excretion in the urine, the periods of the experiment were the most convenient for the purpose. The total amount of nitrogen eliminated in the urine was determined, and also the heat of combustion of the organic matter. In experiments Nos. 431-441, which covered two days each, the determinations were made in the urine for the whole period of an experiment rather than in that for separate days; but in experiments Nos. 442-462 the urine for each day was weighed and analyzed by itself.

ANALYSES OF FOODS AND EXCRETORY PRODUCTS.

Analyses, including determinations of heats of combustion, were made of flours, breads, and all other food materials used in the experiments except sugar, lard, and apples, and also of all excretory products, the methods of analysis followed being for the most part those recommended by the Association of Official Agricultural Chemists.^b The determinations of the ether extract in the feces were unsatisfactory, duplicate determinations failing to give sufficiently concordant results.

^a U. S. Dept. Agr., Office of Experiment Stations Bul. 85, p. 11.

^b U. S. Dept. Agr., Division of Chemistry Bul. 46, revised edition.

The heats of combustion of food, feces, and urine were determined by burning samples of dried material in the bomb calorimeter^a in the usual manner. The milk and urine were prepared for combustion according to Kellner's method, as follows: A weighed absorption block of cellulose,^b previously dried for two days over sulphuric acid, was placed in a platinum capsule and saturated with a known amount of milk or urine. The capsule and block were then dried at a temperature not exceeding 70° C., after which the absorption block was again saturated with a known amount of substance and dried. The block and material were then burned and the results obtained were corrected for the heat of combustion of the absorption block itself, this latter factor being the average of determinations for a considerable number of blocks.

COMPOSITION OF FOOD MATERIALS.

The results of analyses of the flours and all food materials used in these experiments are given in Table 1.

TABLE 1.—Composition of flours and foods used in digestion experiments Nos. 431-462.

Sample number.	Kind of material.	Water.	Protein ^c (N×6.25).	Fat.	Carbo- hy- drates.	Ash.	Heat of combus- tion per gram.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Calories.
✓ 6133	Flour:						
	Straight grade from hard spring						
	wheat	11.55	12.75	1.43	73.67	0.60	3.889
6443	Do	10.90	14.19	1.40	73.02	.49	3.963
6597	Blended flour from soft winter						
	wheat	13.35	10.56	1.11	71.40	.58	3.799
✓ 6142	Entire wheat from same lot as 6133.	10.99	13.00	2.28	72.51	1.22	3.944
6444	Entire wheat from same lot as 6413.	10.43	14.88	1.85	71.95	.89	4.013
6598	Entire wheat from same lot as 6597.	12.94	11.81	1.29	73.27	.69	3.806
✓ 6155	Graham flour from same lot as 6133.	10.51	14.00	2.52	70.97	2.00	4.004
6442	Graham flour from same lot as 6443.	10.61	15.63	2.09	69.91	1.76	3.991
6131	White bread from flour No. 6133.	37.35	9.21	1.79	50.72	.93	2.829
6132	do	43.10	8.10	2.47	45.47	.86	2.626
6195	do	40.32	8.26	1.56	49.19	.67	2.722
6196	do	39.47	8.37	1.65	49.57	.94	2.711
6446	White bread from flour No. 6443.	37.90	9.75	1.54	48.89	1.92	2.752
6447	do	38.54	9.71	1.57	48.28	1.90	2.726
6448	do	38.79	9.65	1.61	48.20	1.75	2.693
6655	White bread from flour No. 6597.	42.16	6.59	.46	49.05	1.74	2.415
6656	do	42.58	6.64	.40	48.57	1.81	2.378
6657	do	41.81	6.58	.39	49.34	1.88	2.397
6695	do	42.70	6.55	.30	48.66	1.79	2.365
6696	do	42.98	6.54	.30	48.47	1.71	2.360
6697	do	42.64	6.50	.26	48.85	1.75	2.408
6143	Entire-wheat bread from flour No. 6142.	44.77	8.04	2.60	43.32	1.27	2.544
6144	do	48.41	7.57	1.93	41.10	.99	2.330
6145	do	43.06	7.76	2.28	45.98	.92	2.595
6471	Entire-wheat bread from flour No. 6444.	37.86	9.95	1.78	48.63	1.78	2.705
6472	do	38.11	9.76	1.84	48.23	2.06	2.754
6473	do	38.07	9.67	1.80	48.58	1.88	2.748
6632	Entire-wheat bread from flour No. 6598.	41.65	7.40	.34	48.80	1.81	2.327
6633	do	40.80	7.37	.37	49.51	1.95	2.463
6634	do	41.80	7.27	.36	48.52	2.05	2.416
6673	do	43.51	7.06	.35	47.10	1.95	2.339
6674	do	43.25	7.16	.42	47.25	1.93	2.367
6675	do	43.38	6.73	.38	47.63	1.88	2.346
6156	Graham bread from flour No. 6155.	45.01	7.97	2.41	43.05	1.56	2.484

^aJour. Amer. Chem. Soc., 25 (1903), p. 659.^bLandw. Vers. Stat., 47 (1896), p. 297.^cCurrent usage is here followed in the factor 6.25, which assumes 16 per cent of nitrogen in protein in the different products. It would, of course, be more correct to adapt the factor to the actual composition which is variable. See Atwater and Bryant, Connecticut (Storrs) Station Rpt., 1899, p. 76.

TABLE 1.—*Composition of flours and foods used in digestion experiments Nos. 431-462—*
Continued.

Sample number.	Kind of material.	Water.	Protein (N × 6.25).	Fat.	Carbo- hy- drates.	Ash.	Heat of combustion per gram.
		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Calories.</i>
6157	Graham bread from flour No. 6155.	44.99	8.07	2.56	42.97	1.41	2,544
6493	Graham bread from flour No. 6442.	39.29	10.25	2.14	45.83	2.49	2,712
6494	do	38.85	10.33	2.16	46.06	2.60	2,735
6495	do	39.56	10.08	2.09	45.75	2.52	2,693
6451	Beef, corned.	54.66	25.44	16.59	.....	3.67	2,959
6475	do	72.35	21.16	3.81	.....	2.22	1,537
6497	do	70.05	22.14	4.66	.....	2.92	1,654
6635	do	71.92	22.30	1.19	.....	1.53	1,336
6676	do	71.56	22.26	1.79	.....	1.14	1,390
6452	Chicken, canned	57.16	27.66	13.62	.....	2.00	2,715
6476	do	58.75	27.16	12.53	.....	2.27	2,658
6498	do	58.25	27.56	12.55	.....	1.96	2,703
6636	do	57.72	27.78	12.76	.....	2.22	2,692
6677	do	57.72	28.22	12.08	.....	2.06	2,685
6450	Potatoes, boiled	56.40	3.41	.11	38.64	1.44	1,707
6637	do	74.58	2.55	.04	21.85	.98	1,011
6678	do	76.22	2.48	.06	20.27	.97	.959
6454	Peaches, canned ^a	84.55	.56	.....	14.59	.30	.533
6639	do	85.28	.31	.....	14.00	.41	.689
6135	Milk, whole	86.18	3.63	4.70	4.67	.82	.835
6148	do	86.51	3.44	5.00	4.26	.79	.845
6159	do	85.49	3.63	5.80	4.27	.81	.946
6198	do	86.76	3.31	4.40	4.78	.75	.812
6453	do	86.44	3.56	4.28	5.04	.68	.712
6477	do	86.37	3.81	4.30	5.52	.69	.811
6499	do	86.25	3.69	4.30	5.07	.69	.626
6134	Butter	16.01	1.19	79.25	.....	3.55	^a 7.436
6146	do	12.59	.44	85.13	.....	1.84	^a 7.917
6147	do	9.97	.44	80.21	.....	9.38	^a 7.484
6158	do	11.96	.50	85.49	.....	2.05	^a 7.951
6197	do	19.23	.44	77.23	.....	3.10	^a 7.207
6449	do	7.66	1.13	88.04	.11	2.76	7.596
6474	do	11.07	.94	84.46	1.62	1.91	7.340
6496	do	9.53	.88	87.27	.66	1.66	7.744
6638	do, ^b	9.42	.88	86.69	.90	2.11	7.392
6679	do, ^b	9.42	1.12	86.45	.90	2.11	7.408
	Apples ^c	84.60	.40	.50	14.20	.30	.290
	Sugar ^c	.....	.....	.....	100.00	.....	3.959
	Lard ^c	.....	.....	100.00	.....	.....	9.300

^aEnergy computed by use of factors, 5.5 calories per gram for protein and 9.3 calories for fat.^bComposition in part assumed from other analyses.^cComposition assumed.

COMPOSITION OF FECES.

The composition of the feces collected in the experiments with different kinds of bread is shown in Table 2, the results being calculated to a water-free basis, since the amount of water in the fresh feces has no bearing upon the calculation of the results of the digestion experiments.

TABLE 2.—*Composition of water-free substance of feces from digestion experiments Nos. 431-462.*

Sample number.	Whence obtained.	Nitrogen.	Protein (N×6.25).	Fat.	Carbohy- drates.	Ash.	Heat of combustion per gram.
		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Calories.</i>
6136	Experiment No. 431.	5.86	36.60	19.89	25.63	17.88	5.720
6137	Experiment No. 432.	4.45	27.83	15.61	36.64	19.92	5.928
6138	Experiment No. 433.	3.97	24.83	14.30	40.00	20.87	5.790
6149	Experiment No. 434.	5.63	35.17	14.55	36.14	14.14	5.399
6150	Experiment No. 435.	4.19	26.17	16.65	40.04	17.11	5.712
6151	Experiment No. 436.	5.23	32.73	14.66	38.63	13.98	5.437
6160	Experiment No. 437.	3.57	22.30	11.74	53.43	12.53	5.015
6161	Experiment No. 438.	3.06	19.16	10.75	53.96	16.13	5.172
6162	Experiment No. 439.	3.44	21.51	11.62	53.31	13.96	5.071
6199	Experiment No. 440.	6.05	37.83	19.80	24.94	17.43	5.841
6200	Experiment No. 441.	3.95	24.68	15.51	39.85	19.96	6.273
6456	Experiment No. 442.	7.10	44.36	14.70	29.47	11.47	5.545
6457	Experiment No. 443.	7.98	49.88	14.58	21.36	14.18	5.552
6458	Experiment No. 444.	7.06	44.15	17.61	20.49	17.75	6.955
6478	Experiment No. 445.	6.78	42.40	9.43	34.52	13.65	5.112
6479	Experiment No. 446.	6.85	42.84	9.81	32.59	14.76	5.094
6480	Experiment No. 447.	6.54	40.87	12.84	32.68	13.61	5.264
6500	Experiment No. 448.	5.02	31.38	7.77	47.03	13.82	4.820
6501	Experiment No. 449.	5.32	33.27	10.19	42.50	14.04	5.113
6502	Experiment No. 450.	4.03	25.19	8.91	50.96	14.94	4.706
6640	Experiment No. 451.	7.49	46.83	16.59	23.18	13.40	5.540
6641	Experiment No. 452.	8.24	51.51	12.23	25.72	10.54	5.529
6642	Experiment No. 453.	7.74	48.37	15.64	24.35	11.64	5.573
6658	Experiment No. 454.	7.62	47.65	16.53	22.52	13.30	5.482
6659	Experiment No. 455.	8.53	53.32	11.35	24.24	11.09	5.508
6660	Experiment No. 456.	8.65	54.06	15.22	20.12	10.60	5.751
6680	Experiment No. 457.	7.43	46.41	16.62	23.45	13.52	5.517
6681	Experiment No. 458.	8.34	52.15	10.52	27.30	10.03	5.510
6682	Experiment No. 459.	7.71	48.18	15.86	23.95	12.01	5.621
6698	Experiment No. 460.	7.70	48.10	15.95	22.30	13.65	5.519
6699	Experiment No. 461.	8.58	53.62	12.12	23.42	10.84	5.618
6700	Experiment No. 462.	7.80	48.74	15.38	23.71	12.17	5.598

STATISTICS OF URINE.

The following table shows the amount, nitrogen content, and heat of combustion of the urine as collected in the different experiments:

TABLE 3.—*Nitrogen content and heat of combustion of urine in digestion experiments Nos. 431-462.*

Sample number.	Subject.	Whence obtained.	Weight of urine.	Nitrogen in urine.		Heat of combustion of urine.	
				Proportion.	Amount.	Per gram.	Total.
			<i>Grams.</i>	<i>Per cent.</i>	<i>Grams.</i>	<i>Calories.</i>	<i>Calories.</i>
6139	P. H. M.	Experiment No. 431	2,192	1.60	35.07	0.122	267.4
6140	J. C. T.	Experiment No. 432	1,163	1.67	19.42	.088	102.4
6141	W. B. W.	Experiment No. 433	1,305	2.06	26.88	.158	206.2
6152	P. H. M.	Experiment No. 434	2,610	1.06	27.67	.088	229.7
6153	J. C. T.	Experiment No. 435	1,035	1.80	18.63	.164	169.7
6154	W. B. W.	Experiment No. 436	1,326	1.78	23.60	.154	204.2
6163	P. H. M.	Experiment No. 437	2,960	1.04	30.78	.086	254.6
6164	J. C. T.	Experiment No. 438	1,046	1.73	18.10	.154	161.1
6165	W. B. W.	Experiment No. 439	1,385	1.74	24.10	.146	202.3
6202	P. H. M.	Experiment No. 440	1,889	1.22	23.05	.111	209.7
6203	J. C. T.	Experiment No. 441	1,046	1.72	17.99	.151	157.9
		E. R. M.	Experiment No. 442:				
6459		First day	1,209	.93	11.24	.069	83
6462		Second day	1,492	.95	14.17	.074	110
6465		Third day	1,405	1.02	14.33	.070	98
6468		Fourth day	1,398	1.21	16.92	.069	93
			Total for 4 days		56.66		384
		J. E. F.	Experiment No. 443:				
6460		First day	861	1.57	13.52	.124	107
6463		Second day	1,102	1.32	14.55	.099	109
6466		Third day	783	1.39	10.88	.094	74
6469		Fourth day	759	1.44	10.93	.102	77
			Total for 4 days		49.88		367

TABLE 3.—*Nitrogen content and heat of combustion of urine in digestion experiments Nos. 431-462—Continued.*

Sample number.	Subject.	Whence obtained.	Weight of urine.	Nitrogen in urine.		Heat of combustion of urine.	
				Proportion.	Amount.	Per gram.	Total.
6461	W. H. E...	Experiment No. 444:	<i>Grams.</i>	<i>Per cent.</i>	<i>Grams.</i>	<i>Calories.</i>	<i>Calories.</i>
6464		First day	1,211	0.93	11.26	.085	103
6467		Second day	970	1.39	13.49	.107	104
6470		Third day	1,034	1.59	16.44	.116	120
		Fourth day	731	1.55	11.33	.118	86
		Total for 4 days.....	3,946		52.52		413
6481	E. R. M...	Experiment No. 445:					
6484		First day	1,099	1.20	13.19	.073	80
6487		Second day	1,282	1.43	18.33	.067	86
6490		Third day	1,218	1.01	12.30	.072	88
		Fourth day	1,238	1.37	16.96	.086	107
		Total for 4 days.....	4,837		60.78		361
6482	J. E. F....	Experiment No. 446:					
6485		First day	772	1.18	9.11	.071	55
6488		Second day	1,229	1.41	17.33	.092	113
6491		Third day	1,181	1.52	17.95	.087	103
		Fourth day	830	1.85	15.35	.085	71
		Total for 4 days.....	4,012		59.74		342
6483	W. H. E...	Experiment No. 447:					
6486		First day	1,222	1.05	12.83	.067	82
6489		Second day	1,094	1.48	16.19	.082	88
6492		Third day	915	1.48	13.54	.113	104
		Fourth day	1,079	1.87	20.18	.114	123
		Total for 4 days.....	4,310		62.74		397
6503	E. R. M...	Experiment No. 448:					
6506		First day	1,163	1.51	17.56	.108	126
6509		Second day	1,451	1.20	17.11	.082	119
6512		Third day	1,638	1.12	18.35	.062	102
		Fourth day	1,165	1.10	12.82	.033	79
		Total for 4 days.....	5,417		66.14		426
6504	J. E. F....	Experiment No. 449:					
6507		First day	411	1.18	4.95	.091	37
6510		Second day	762	1.61	12.27	.115	88
6513		Third day	938	1.43	14.27	.091	91
		Fourth day	1,043	1.50	15.65	.093	97
		Total for 4 days.....	3,214		47.14		313
6505	W. H. E...	Experiment No. 450:					
6508		First day	1,270	.94	11.94	.061	78
6511		Second day	1,289	1.41	18.17	.100	129
6514		Third day	1,043	1.94	20.23	.107	112
		Fourth day	1,072	1.60	17.15	.105	113
		Total for 4 days.....	4,674		67.49		432
6643	E. F. B....	Experiment No. 451:					
6646		First day	1,230	1.09	13.4	.091	112
6649		Second day	1,707	1.10	18.8	.084	143
6652		Third day	1,222	1.19	14.5	.085	104
		Fourth day	922	1.04	9.6	.108	100
		Total for 4 days.....	5,081		56.3		459
6644	E. R. M...	Experiment No. 452:					
6647		First day	1,076	.75	8.0	.073	79
6650		Second day	1,371	.85	11.7	.080	109
6653		Third day	1,329	.94	12.5	.086	114
		Fourth day	1,423	1.04	14.8	.094	134
		Total for 4 days.....	5,199		47.0		436

TABLE 3.—*Nitrogen content and heat of combustion of urine in digestion experiments Nos. 431-462—Continued.*

Sample number.	Subject.	Whence obtained.	Weight of urine.	Nitrogen in urine.		Heat of combustion of urine.	
				Proportion.	Amount.	Per gram.	Total.
	E. E. N.	Experiment No. 453:	<i>Grams.</i>	<i>Per cent.</i>	<i>Grams.</i>	<i>Calories.</i>	<i>Calories</i>
6645	.....	First day	172	0.92	15.7	0.090	154
6648	.....	Second day	2,266	.87	19.7	.069	155
6651	.....	Third day	1,390	.99	13.8	.096	133
6654	.....	Fourth day	936	1.05	9.8	.101	95
		Total for 4 days	5,304	.....	59.0	.....	537
	E. F. B.	Experiment No. 454:					
6661	.....	First day	1,838	.69	12.7	.068	122
6664	.....	Second day	1,260	1.06	13.4	.086	108
6667	.....	Third day	1,186	1.11	13.1	.086	102
6670	.....	Fourth day	730	.96	7.0	.121	88
		Total for 4 days	5,014	.....	46.2	.....	420
	E. R. M.	Experiment No. 455:					
6662	.....	First day	1,269	.86	10.9	.069	88
6665	.....	Second day	1,377	.72	9.9	.065	90
6668	.....	Third day	1,448	.87	12.6	.110	159
6671	.....	Fourth day ^a					
		Total for 3 days	4,094	.....	33.4	.....	337
	E. E. N.	Experiment No. 456:					
6663	.....	First day	1,638	.90	14.7	.075	123
6666	.....	Second day	1,590	.78	12.4	.069	100
6669	.....	Third day	1,892	.60	11.4	.098	185
6672	.....	Fourth day	2,179	.85	18.5	.122	266
		Total for 4 days	7,299	.....	57.0	.....	674
	E. F. B.	Experiment No. 457:					
6683	.....	First day	1,470	.96	14.0	.098	144
6686	.....	Second day	1,257	1.04	13.1	.115	145
6689	.....	Third day	1,306	1.08	14.1	.113	148
6692	.....	Fourth day	768	.90	6.9	.123	94
		Total for 4 days	4,801	.....	48.1	.....	530
	E. R. M.	Experiment No. 458:					
6684	.....	First day	1,205	.86	10.4	.117	141
6687	.....	Second day	1,462	.62	9.1	.084	123
6690	.....	Third day	1,356	.74	10.0	.102	138
6693	.....	Fourth day	1,273	.88	11.2	.109	139
		Total for 4 days	5,296	.....	40.7	.....	541
	E. E. N.	Experiment No. 459:					
6685	.....	First day	2,179	.54	11.8	.081	176
6688	.....	Second day	1,450	.84	12.2	.115	122
6691	.....	Third day	1,502	.90	13.5	.117	176
6694	.....	Fourth day	853	1.00	8.5	.139	117
		Total for 4 days	5,984	.....	46.0	.....	591
	E. F. B.	Experiment No. 460:					
6701	.....	First day	1,327	1.09	14.5	.104	138
6704	.....	Second day	1,407	.90	12.7	.114	160
6707	.....	Third day	1,400	1.00	14.0	.120	168
6710	.....	Fourth day	607	1.33	8.0	.098	60
		Total for 4 days	4,741	.....	49.2	.....	526
	E. R. M.	Experiment No. 461:					
6702	.....	First day	1,064	.83	8.8	.099	105
6705	.....	Second day	1,451	.73	10.6	.111	161
6708	.....	Third day	1,349	.77	10.4	.085	115
6711	.....	Fourth day	1,364	1.12	15.3	.080	109
		Total for 4 days	5,228	.....	45.1	.....	490
	E. E. N.	Experiment No. 462:					
6703	.....	First day	2,123	.83	17.6	.113	240
6706	.....	Second day	1,560	.70	10.9	.099	154
6709	.....	Third day	1,644	.89	14.6	.095	156
6712	.....	Fourth day	851	1.09	9.3	.108	90
		Total for 4 days	6,178	.....	52.4	.....	64

^aThe urine for this day was accidentally lost.

The experiments of this series, Nos. 431-441, in which the purpose was to determine the digestibility of the different kinds of bread alone, covered short periods, namely, two days each. The white bread was made from flour No. 6133, the entire-wheat bread from No. 6142, and the Graham bread from No. 6155, described on pages 10 and 11, all of which were ground from the same lot of hard spring wheat. The diet was very simple, consisting of the bread studied and enough milk, butter, and sugar to enable the subject to eat it with relish. Some coffee was taken as a beverage, but as this contained a negligible amount of nutrients, it is not included in the tables. The crust of the bread was rejected, only the crumb being used. Each man was allowed, within certain limits, to eat as much as he pleased.

The subjects were students from 19 to 23 years of age. The youngest and heaviest of these was of somewhat more active habits than the others and had a more vigorous appetite. Toward the close of the experiments he went into training for athletic field contests, which markedly increased the amount of food eaten.

As noted elsewhere,^a it seems to be the case that the various articles of food which comprise a mixed diet are more digestible than the same articles when eaten alone. For this reason, as well as to increase the palatability of the diet over that of a ration of bread alone, it was thought best to allow the use of the other foods mentioned with the bread experimented on. In order to calculate the digestibility of the bread alone from the results obtained with a diet of such a nature, it was necessary to assume values for the digestibility of the accessory foods. The factors used in the experiments previously reported were: For fats of milk and butter, 99 per cent; for protein of milk and butter, 98 per cent; for milk sugar, 98 per cent, and for cane sugar, 99 per cent. These figures are more or less arbitrary, but they were based on the best information available. With the exception that the factor 98 per cent was used for both milk and cane sugar, the same figures were employed in the following tables in computing the "estimated feces from food other than bread."

The manner in which these factors are applied may be illustrated by figures from experiment No. 431. From Table 4 it will be seen that of the total 227.3 grams of protein consumed in the two days, 79.6 grams was supplied by the milk and butter. If it be assumed that 98 per cent of the protein of milk and butter was digested, the undigested portion, namely, 2 per cent of 79.6 grams, or 1.6 grams, should appear in the feces. The total amount of protein in the feces was 9.4 grams. Deducting from this the undigested protein of the milk and butter, 7.8 grams of the protein of the feces must be credited to the

^aU. S. Dept. Agr., Office of Experiment Stations Bul. 85, p. 15.

bread ingested. The total amount of digestible protein was 217.9 grams; dividing this by the total protein eaten, 227.3 grams, gives 95.9 per cent as the coefficient of digestibility of the total protein in the diet. The protein in the bread eaten was 147.7 grams, of which 7.8 grams appeared undigested in the feces, leaving 139.9 grams of digestible protein from the bread alone; which divided by the total protein contained in the bread eaten, 147.7 grams, gives 94.7 per cent as the estimated coefficient of digestibility of the protein of the bread alone.

By the use of the other factors given, the digestibility of the fat and carbohydrates are similarly computed.

The method of calculating the proportion of energy actually available to the body may likewise be illustrated by applying it in experiment No. 431. Here the digestible protein from the whole diet, 217.9 grams, multiplied by 1.25, the average number of calories which it is assumed would escape in the organic matter of the urine for every gram of protein digested from the food, gives 272 calories as the amount of energy lost in the urine through incomplete oxidation. If this amount be deducted from the total energy of the digested food, 8,233 calories, the difference, 7,961 calories, represents the energy of the total food actually oxidized in the body. The proportion of the energy of the total food that would be actually available to the body, 95 per cent, is the quotient obtained by dividing the energy of food oxidized, 7,961 calories, by the total energy of the food eaten, 8,379 calories.

By a similar process the energy from the bread alone that was actually utilized by the body may likewise be computed, only in this case it is first necessary to estimate the energy of the digestible nutrients of the bread. For this purpose the energy of the feces from food other than bread was computed by use of factors (for protein 5.65, for fat 9.4, and for carbohydrates 4.15 calories per gram), and this was subtracted from the energy of the total feces as determined, the remainder being taken as the energy of the estimated feces from bread. The difference between this and the total energy of the bread is the energy of the digestible nutrients of the bread. In the case of experiment No. 431 this was 4,571 calories. The energy lost in the urine corresponding to the digestible protein of the bread was $(139.9 \times 1.25 =)$ 175 calories, which subtracted from the energy of the digestible nutrients of the bread gives 4,396 calories as the total amount of energy from bread actually oxidized in the body. Dividing this by the total in the bread consumed, 4,667 calories, gives the proportion of the energy of the bread actually available to the body, 94.2 per cent.

Although the energy of the urine was determined, in the calculation of the availability of the energy of the total food and of the bread alone it was assumed, principally for the sake of uniformity with exper-

iments previously reported, that 1.25 calories of energy would appear in the urine for every gram of digestible protein in the total food or in the bread alone. The relation of the values determined to the factor is discussed elsewhere (p. 52).

The details of the experiments follow:

DIGESTION EXPERIMENT NO. 431.

Kind of food.—White bread, with milk, butter, and sugar.

Subject.—P. H. M.

Weight.—At beginning, 182.2 pounds; at close, 179 pounds.

Duration.—Two days, with six meals.

TABLE 4.—Results of digestion experiment No. 431.

Sample number.		Weight of material.	Total organic matter.	Protein (N \times 6.25).	Fat.	Carbohydrates.	Ash.	Energy.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
6131	White bread	782.0	482.7	72.0	14.0	396.7	7.6	2,212
6132	do.	934.8	523.8	75.7	23.1	425.0	8.0	2,455
6134	Butter	209.6	168.6	2.5	166.1	.....	7.4	1,558
6135	Milk	2,125.0	276.3	77.1	99.9	99.3	17.4	1,774
	Sugar	95.2	95.2	.....	.....	95.2	.....	380
	Total		1,546.6	227.3	303.1	1,016.2	40.1	8,379
6136	Feces	25.6	21.0	9.1	5.1	6.5	4.6	146
	Estimated feces from food other than bread		8.2	1.6	2.7	3.9	.....	50
	Estimated feces from bread		12.8	7.8	2.4	2.6	.....	96
	Total amount digested		1,525.6	217.9	298.0	1,009.7	35.5	8,233
	Estimated digestible nutrients in bread		993.7	139.9	34.7	819.1	.....	4,571
		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
	Coefficients of digestibility of total food		98.6	95.9	98.3	99.4	88.5	(98.3)
	Estimated coefficients of digestibility of bread alone		98.7	94.7	93.5	99.7	.....	(97.9)
	Proportion of energy actually available to body:							
	In total food							95.0
	In bread alone							94.2

During this experiment the subject eliminated 2,192 grams of urine containing 1.60 per cent, or 35.1 grams, nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 18.2 grams; outgo in urine and feces, 18.3 grams; making a loss of 0.1 gram nitrogen, corresponding to 0.6 gram protein.

DIGESTION EXPERIMENT NO. 432.

Kind of food.—White bread, with milk, butter, and sugar.

Subject.—J. C. T.

Weight (without clothing).—At beginning, 121.6 pounds; at end, 121.4 pounds.

Duration.—Two days, with six meals.

TABLE 5.—Results of digestion experiment No. 432.

Sample number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbo-hydrates.	Ash.	Energy.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
6131	White bread	517.6	319.5	47.7	9.3	262.5	4.8	1,464
6132	do.	646.4	362.2	52.4	16.0	293.8	5.6	1,697
6134	Butter	247.0	198.7	2.9	195.8	.....	8.8	1,837
6135	Milk	1,075.0	139.7	39.0	50.5	50.2	8.8	898
	Sugar	93.8	93.8	.....	.....	93.8	.....	374
	Total		1,113.9	142.0	271.6	700.3	28.0	6,270
6137	Feces	34.6	27.7	9.6	5.4	12.7	6.9	205
	Estimated feces from food other than bread		6.2	.8	2.5	2.9	.....	40
	Estimated feces from bread		21.5	8.8	2.9	9.8	.....	165
	Total amount digested.		1,086.2	132.4	266.2	687.6	21.1	6,065
	Estimated digestible nutrients in bread		660.2	91.3	22.4	546.5	.....	2,996
		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
	Coefficients of digestibility of total food		97.5	93.2	98.0	98.2	75.4	(96.7)
	Estimated coefficients of digestibility of bread alone		96.9	91.2	88.5	98.2	.....	(94.8)
	Proportion of energy actually available to body:							
	In total food							94.1
	In bread alone							91.2

During this experiment the subject eliminated 1,163 grams of urine containing 1.67 per cent, or 19.4 grams, nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 11.3 grams; outgo in urine and feces, 10.4 grams; making a gain of 0.9 gram nitrogen, corresponding to 5.6 grams protein.

DIGESTION EXPERIMENT NO. 433.

Kind of food.—White bread, with milk, butter, and sugar.

Subject.—W. B. W.

Weight (without clothing).—At beginning, 144.7 pounds; at close, 142.6 pounds.

Duration.—Two days, with six meals.

TABLE 6.—Results of digestion experiment No. 433.

Sample number.		Weight of material.	Total organic matter.	Protein (N \times 6.25).	Fat.	Carbohy- drates.	Ash.	Energy.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
6131	White bread	521.4	321.9	48.0	9.4	264.5	4.8	1,475
6131	.....do.....	605.8	339.5	49.1	15.0	275.4	5.2	1,591
6134	Butter	191.2	153.8	2.3	151.5	.....	6.8	1,422
6135	Milk	1,475.0	191.8	53.8	69.3	68.9	12.1	1,232
	Sugar	39.8	39.8	.....	.....	39.8	.....	159
	Total.....	.....	1,046.8	153.0	245.2	648.6	28.9	5,879
6138	Feces	22.1	17.5	5.5	3.2	8.8	4.6	128
	Estimated feces from food other than bread .....	.....	5.5	1.1	2.2	2.2	.....	35
	Estimated feces from bread .....	.....	12.0	4.4	1.0	6.6	.....	93
	Total amount digested.....	.....	1,029.3	147.5	242.0	639.8	24.3	5,751
	Estimated digestible nutrients in bread.....	.....	649.4	92.7	23.4	533.3	.....	2,973
		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
	Coefficients of digestibility of total food.....	.....	98.3	96.4	98.7	98.6	84.1	(97.8)
	Estimated coefficients of digestibility of bread alone.....	.....	98.2	95.5	95.9	98.8	.....	(97.0)
	Proportion of energy actually available to body:							
	In total food.....	.....	.....	.....	.....	.....	.....	94.7
	In bread alone.....	.....	.....	.....	.....	.....	.....	93.2

During this experiment the subject eliminated 1,305 grams of urine containing 2.06 per cent, or 26.9 grams, nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 12.2 grams; outgo in urine and feces, 13.9 grams; making a loss of 1.7 grams nitrogen, corresponding to 10.5 grams protein.

DIGESTION EXPERIMENT NO. 434.

Kind of food.—Entire-wheat bread, with milk, butter, and sugar.

Subject.—P. H. M.

Weight (without clothing).—At beginning, 180.3 pounds; at close, 179.5 pounds.

Duration.—Two days, with six meals.

TABLE 7.—Results of digestion experiment No. 434.

Sample number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohy- drates.	Ash.	Energy.
		Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories.
6143	Entire-wheat bread.....	562.6	303.5	45.2	14.6	243.7	7.1	1,431
6144	.....do.....	652.2	330.0	49.4	12.6	268.0	6.5	1,519
6145	.....do.....	692.0	387.8	53.7	15.8	318.3	6.4	1,796
6146	Butter.....	99.0	84.7	.4	84.3	.....	1.8	786
6147	.....do.....	95.6	77.1	.4	76.7	.....	9.0	716
6148	Milk.....	1,450.0	184.2	49.9	72.5	61.8	11.5	1,225
	Sugar.....	102.6	102.6	.....	.....	102.6	.....	409
	Total.....		1,469.9	199.0	276.5	994.4	42.3	7,882
6149	Feces.....	78.9	67.8	27.8	11.5	28.5	11.1	426
	Estimated feces from food other than bread.....		6.6	1.0	2.3	3.3	.....	40
	Estimated feces from bread.....		61.2	26.8	9.2	25.2	.....	386
	Total amount digested.....		1,402.1	171.2	265.0	965.9	31.2	7,456
	Estimated digestible nutrients in bread.....		960.1	121.5	33.8	804.8	.....	4,360
		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
	Coefficients of digestibility of total food.....		95.4	86.0	95.8	97.1	73.5	(94.6)
	Estimated coefficients of digestibility of bread alone.....		94.0	81.9	78.6	97.0	.....	(91.9)
	Proportion of energy actually available to body:							
	In total food.....							91.9
	In bread alone.....							88.7

During this experiment the subject eliminated 2,610 grams of urine containing 1.06 per cent, or 27.7 grams, nitrogen. This makes the average balance per day as follows: Income in food, 16 grams; outgo in urine and feces, 16.1 grams; making a loss of 0.1 gram nitrogen, corresponding to 0.6 gram protein.

DIGESTION EXPERIMENT NO. 435.

Kind of food.—Entire-wheat bread, with milk, butter, and sugar.

Subject.—J. C. T.

Weight (without clothing).—At beginning, 119.9 pounds; at close, 121.4 pounds.

Duration.—Two days, with six meals.

TABLE 8.—Results of digestion experiment No. 435.

Sample number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohy- drates.	Ash.	Energy.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
6143	Entire-wheat bread.....	394.0	212.6	31.7	10.2	170.7	5.0	1,002
6144	.....do.....	413.6	209.3	31.3	8.0	170.0	4.1	964
6145	.....do.....	506.0	283.5	39.3	11.5	232.7	4.7	1,313
6146	Butter.....	208.2	178.2	.9	177.3	.....	3.8	1,654
6147	.....do.....	92.0	74.2	.4	73.8	.....	8.6	689
6148	Milk.....	875.0	111.1	30.1	43.7	37.3	6.9	740
	Sugar.....	99.0	99.0	.....	.....	99.0	.....	395
	Total.....	.....	1,167.9	133.7	324.5	709.7	33.1	6,757
6150	Feces.....	85.5	70.9	22.4	14.3	34.2	14.6	488
	Estimated feces from food other than bread.....	.....	6.2	.6	2.9	2.7	.....	43
	Estimated feces from bread.....	.....	64.7	21.8	11.4	31.5	.....	445
	Total amount digested.....	.....	1,097.0	111.3	310.2	675.5	18.5	6,269
	Estimated digestible nutri- ents in bread.....	.....	640.7	80.5	18.3	541.9	.....	2,824
		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
	Coefficients of digestibility of total food.....	.....	93.9	83.2	95.6	95.2	55.9	(92.8)
	Estimated coefficients of di- gestibility of bread alone.....	.....	90.8	78.7	61.6	91.5	.....	(86.4)
	Proportion of energy actu- ally available to body:	.....	.....	.....	.....	.....	.....	.....
	In total food.....	.....	.....	.....	.....	.....	.....	90.7
	In bread alone.....	.....	.....	.....	.....	.....	.....	83.4

During this experiment the subject eliminated 1,035 grams of urine containing 1.80 per cent, or 18.6 grams, nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 10.7 grams; outgo in urine and feces, 11.1 grams; making a loss of 0.4 gram nitrogen, corresponding to 2.5 grams protein.

DIGESTION EXPERIMENT NO. 436.

Kind of food.—Entire-wheat bread, with milk, butter, and sugar.

Subject.—W. B. W.

Weight (without clothing).—At beginning, 144.4 pounds; at close, 143.1 pounds.

Duration.—Two days, six meals.

TABLE 9.—Results of digestion experiment No. 436.

Sample number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohy- drates.	Asb.	Energy.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
6143	Entire-wheat bread.....	286.8	154.9	23.1	7.5	124.3	3.6	730
6144	.....do.....	461.4	233.5	34.9	8.9	189.7	4.6	1,075
6145	.....do.....	440.2	246.6	34.2	19.0	202.4	4.1	1,143
6146	Butter.....	100.0	85.5	.4	85.1	.....	1.8	794
6147	.....do.....	97.4	78.5	.4	78.1	.....	9.1	729
6148	Milk.....	850.0	107.9	29.2	42.5	56.2	6.7	718
	Sugar.....	48.8	48.8	.....	.....	48.8	.....	195
	Total.....	.....	955.7	122.2	232.1	601.4	29.9	5,384
6151	Feces.....	53.1	45.7	17.4	7.8	20.5	7.4	289
	Estimated feces from food other than bread.....	.....	4.4	.6	2.1	1.7	.....	29
	Estimated feces from bread.....	.....	41.3	16.8	5.7	18.8	.....	260
	Total amount digested.....	.....	910.0	104.8	224.3	580.9	22.5	5,095
	Estimated digestible nutrients in bread.....	.....	593.7	75.4	20.7	497.6	.....	2,688
		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
	Coefficients of digestibility of total food.....	.....	95.2	85.7	96.6	96.6	75.3	(94.6)
	Estimated coefficients of digestibility of bread alone.....	.....	93.5	81.8	78.4	96.4	.....	(91.2)
	Proportion of energy actually available to body:							
	In total food.....	.....	.....	.....	.....	.....	.....	92.2
	In bread alone.....	.....	.....	.....	.....	.....	.....	88.0

During this experiment the subject eliminated 1,326 grams of urine containing 1.78 per cent, or 23.6 grams, nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 9.8 grams; outgo in urine and feces, 13.2 grams; making a loss of 3.4 grams nitrogen, corresponding to 21.2 grams protein.

DIGESTION EXPERIMENT NO. 437.

Kind of food.—Graham bread, with milk, butter, and sugar.

Subject.—P. H. M.

Weight (without clothing).—At beginning, 178.5 pounds; at close, 179.3 pounds.

Duration.—Two days, with six meals.

TABLE 10.—Results of digestion experiment No. 437.

Sample number.		Weight of material.	Total organic matter.	Protein (N × 6.25).	Fat.	Carbohy- drates.	Ash.	Energy.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
6156	Graham bread	956.2	510.8	76.2	23.0	411.6	14.9	2,376
6157	.....do.....	977.2	523.8	78.9	25.0	419.9	13.8	2,457
6158	Butter	197.4	169.8	1.0	168.8	.....	4.0	1,575
6159	Milk	2,125.0	291.2	77.2	123.2	90.8	17.2	2,010
	Sugar	103.0	103.0	.....	.....	103.0	.....	411
	Total .....	.....	1,598.6	233.3	340.0	1,025.3	49.9	8,829
6160	Feces	139.4	121.9	31.1	16.3	74.5	17.5	699
	Estimated feces from food other than bread .....	.....	8.4	1.6	2.9	3.9	.....	51
	Estimated feces from bread .....	.....	113.5	29.5	13.4	70.6	.....	648
	Total amount digested .....	.....	1,476.7	202.2	323.7	950.8	32.4	8,130
	Estimated digestible nutrients in bread .....	.....	921.1	125.6	34.6	760.9	.....	4,185
	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
	Coefficients of digestibility of total food .....	.....	92.4	86.7	95.2	92.7	64.9	(92.1)
	Estimated coefficients of digestibility of bread alone .....	.....	89.0	81.0	72.1	91.5	.....	(86.6)
	Proportion of energy actually available to body:	.....	.....	.....	.....	.....	.....	.....
	In total food .....	.....	.....	.....	.....	.....	.....	89.2
	In bread alone .....	.....	.....	.....	.....	.....	.....	83.4

During this experiment the subject eliminated 2,960 grams urine containing 1.04 per cent, or 30.8 grams, nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 18.6 grams; outgo in urine and feces, 17.9 grams; making a gain of 0.7 gram nitrogen, corresponding to 4.7 grams protein.

DIGESTION EXPERIMENT NO. 438.

Kind of food.—Graham bread, with milk, butter, and sugar.

Subject.—J. C. T.

Weight (without clothing).—At beginning, 119.6 pounds; at close, 120.5 pounds.

Duration.—Two days, with six meals.

TABLE 11.—Results of digestion experiment No. 438.

Sample number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Energy.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
6156	Graham bread	675.8	361.1	53.9	16.3	290.9	10.5	1,679
6157	....do.	507.4	271.9	40.9	13.0	218.0	7.2	1,275
6158	Butter	306.6	263.6	1.5	262.1	.....	6.3	2,446
6159	Milk	875.0	119.9	31.8	50.7	37.4	7.1	828
	Sugar	90.6	90.6	.....	.....	90.6	.....	361
	Total .....	.....	1,107.1	128.1	342.1	636.9	31.1	6,589
6161	Feces	96.7	81.1	18.5	10.4	52.2	15.6	500
	Estimated feces from food other than bread .....	.....	6.4	.7	3.1	2.6	.....	43
	Estimated feces from bread .....	.....	74.7	17.8	7.3	49.6	.....	457
	Total amount digested. ....	.....	1,026.0	109.6	331.7	584.7	15.5	6,089
	Estimated digestible nutrients in bread .....	.....	558.3	77.0	22.0	459.3	.....	2,497
		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
	Coefficients of digestibility of total food .....	.....	92.7	85.6	97.0	91.8	49.8	(92.4)
	Estimated coefficients of digestibility of bread alone .....	.....	88.2	81.2	75.1	90.2	.....	(84.5)
	Proportion of energy actually available to body:							
	In total food .....	.....	.....	.....	.....	.....	.....	90.3
	In bread alone .....	.....	.....	.....	.....	.....	.....	81.3

During this experiment the subject eliminated 1,046 grams of urine containing 1.73 per cent, or 18.1 grams, nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 10.2 grams; outgo in urine and feces, 10.5 grams; making a loss of 0.3 gram nitrogen, corresponding to 1.9 grams protein.

DIGESTION EXPERIMENT NO. 439.

Kind of food.—Graham bread, with milk, butter, and sugar.

Subject.—W. B. W.

Weight (without clothing).—At beginning, 143.2 pounds; at close, 141.7 pounds.

Duration.—Two days, with six meals.

TABLE 12.—Results of digestion experiment No. 439.

Sample number.		Weight of material.	Total organic matter.	Protein (N \times 6.25).	Fat.	Carbohy- drates.	Ash.	Energy.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
6156	Graham bread	689.4	368.3	54.9	16.6	296.8	10.8	1,713
6157	do.	603.4	323.1	48.7	15.4	259.3	8.5	1,517
6158	Butter	206.2	177.3	1.0	176.3	.....	4.2	1,645
6159	Milk	850.0	116.5	30.9	49.3	36.3	6.9	804
	Sugar	60.2	60.2	.....	.....	60.2	.....	240
	Total.....		1,045.7	135.5	257.6	652.6	30.4	5,919
6162	Feces	91.9	79.4	19.7	10.7	49.0	12.5	466
	Estimated feces from food other than bread		1.8	.6	2.3	1.9	.....	32
	Estimated feces from bread		74.6	19.1	8.1	47.1	.....	434
	Total amount digested.....		966.3	115.8	246.9	603.6	17.9	5,453
	Estimated digestible nutri- cients in bread		617.1	84.5	23.6	509.0	.....	2,796
		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
	Coefficients of digestibility of total food		92.4	85.5	95.8	92.5	58.9	(92.1)
	Estimated coefficients of digestibility of bread alone.....		89.2	81.6	73.7	91.5	.....	(86.6)
	Proportion of energy actu- ally available to body:							
	In total food							89.7
	In bread alone.....							83.3

During this experiment the subject eliminated 1,385 grams of urine containing 1.74 per cent, or 24.1 grams, nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 10.8 grams; outgo in urine and feces, 13.6 grams; making a loss of 2.8 grams nitrogen, corresponding to 17.5 grams protein.

DIGESTION EXPERIMENT NO. 440.

Kind of food.—White bread, with milk, butter, and sugar (half ration).

Subject.—P. H. M.

Weight (without clothing).—At beginning, 175.6 pounds; at close, 171.7 pounds.

TABLE 13.—Results of digestion experiment No. 440.

Sample number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohy- drates.	Ash.	Energy.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
6195	White bread.....	301.0	177.6	24.9	4.7	148.0	2.0	819
6196	.....do.....	281.0	167.4	23.5	4.6	139.3	2.6	762
6197	Butter.....	115.5	89.7	.5	89.2	.....	3.6	832
6198	Milk.....	537.5	67.1	17.8	23.6	25.7	4.0	437
	Sugar.....	47.0	47.0	.....	.....	47.0	.....	188
	Total.....	.....	548.8	66.7	122.1	360.0	12.2	3,038
6200	Feces.....	29.5	37.0	11.4	7.2	18.4	9.2	290
	Estimated feces from food other than bread.....	.....	3.0	.4	1.1	1.5	.....	18
	Estimated feces from bread.....	.....	34.0	11.0	6.1	16.9	.....	272
	Total amount digested.....	.....	511.8	55.3	114.9	341.6	3.0	2,748
	Estimated digestible nutrients in bread.....	.....	311.0	37.4	3.2	270.4	.....	1,309
		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
	Coefficients of digestibility of total food.....	.....	93.3	82.9	91.1	94.9	24.6	(90.5)
	Estimated coefficients of digestibility of bread alone.....	.....	90.2	77.3	34.4	94.1	.....	(82.8)
	Proportion of energy actually available to body:	.....	.....	.....	.....	.....	.....	.....
	In total food.....	.....	.....	.....	.....	.....	.....	88.2
	In bread alone.....	.....	.....	.....	.....	.....	.....	79.8

During this experiment the subject eliminated 1,889 grams of urine containing 1.22 per cent, or 23.0 grams, nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 8.5 grams; outgo in urine and feces, 12.5 grams; making a loss of 4 grams nitrogen, corresponding to 24.7 grams protein.

DIGESTION EXPERIMENT NO. 441.

Kind of food.—White bread, with milk, butter, and sugar (half ration).

Subject.—J. C. T.

Weight (without clothing).—At beginning, 116.4 pounds; at close, 115.6 pounds.

Duration.—Two days, with six meals.

TABLE 14.—Results of digestion experiment No. 441.

Sample number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohy- drates.	Ash.	Energy.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
6195	White bread	406.0	239.6	33.5	6.3	199.8	2.7	1,105
6196	do.	441.4	264.8	37.2	7.3	220.3	4.2	1,205
6197	Butter	101.8	81.4	.5	80.9	.....	3.2	755
6198	Milk	1,062.5	132.8	35.2	46.8	50.8	8.0	863
	Sugar	47.6	47.6	.....	.....	47.6	.....	190
	Total		766.2	106.4	141.3	518.5	18.1	4,118
6199	Feces	46.2	24.4	11.2	5.8	7.4	5.1	172
	Estimated feces from food other than bread		1.0	.7	1.3	2.0	.....	24
	Estimated feces from bread		20.4	10.5	4.5	5.4	.....	148
	Total amount digested.		741.8	95.2	135.5	511.1	13.0	3,946
	Estimated digestible nutri- ents in bread		484.0	60.2	9.1	414.7	.....	2,162
		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
	Coefficients of digestibility of total food		96.8	89.5	95.9	98.6	71.8	(95.8)
	Estimated coefficients of di- gestibility of bread alone.		95.9	85.2	66.9	98.7	.....	(93.6)
	Proportion of energy actu- ally available to body:							
	In total food							92.9
	In bread alone							90.4

During this experiment the subject eliminated 1,046 grams of urine containing 1.72 percent, or 18 grams, nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 5.3 grams; outgo in urine and feces, 9.9 grams; making a loss of 4.6 grams nitrogen, corresponding to 28.5 grams protein.

SUMMARY OF RESULTS.

The results given in detail in the foregoing pages are summarized in Tables 15 and 16. The first of these gives the digestibility of the nutrients and availability of the energy of the total food; the second, the calculated digestibility of the nutrients and availability of the energy of the bread alone.

TABLE 15.—*Summary of digestion experiments—Digestibility of nutrients and availability of energy of total food.*

Ex- peri- ment num- ber.	Subject.	Kind of food.	Coefficients of digestibility.					Availa- bility of energy.
			Total organic matter.	Pro- tein.	Fat.	Carbo- hy- drates.	Ash.	
			<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
421	P. H. M ...	White bread, milk, butter, and sugar.....	98.6	95.9	98.3	99.4	88.5	95.0
432	J. C. T.	do.....	97.5	93.2	98.0	98.2	75.4	94.1
433	W. B. W.	do.....	98.3	96.4	98.7	98.6	84.1	94.7
		Average of 3 above.....	98.1	95.2	98.3	98.7	82.7	94.6
434	P. H. M ...	Entire-wheat bread, milk, butter, and sugar.....	95.4	86.0	95.8	97.1	74.4	91.9
435	J. C. T.	do.....	93.9	83.2	95.6	95.2	55.9	90.7
436	W. B. W.	do.....	95.2	85.7	96.6	96.6	75.3	92.2
		Average of 3 above.....	94.8	85.0	96.0	96.3	68.5	91.6
437	P. H. M ...	Graham bread, milk, butter, and sugar.....	92.4	86.7	95.2	92.7	64.9	89.2
438	J. C. T.	do.....	92.7	85.6	97.0	91.8	49.8	90.3
439	W. B. W.	do.....	92.4	85.5	95.8	92.5	58.9	89.7
		Average of 3 above.....	92.5	85.9	96.0	92.3	57.9	89.7
440	P. H. M ...	White bread, milk, butter, and sugar (half ration)	96.8	89.5	95.9	98.6	71.8	93.0
441	J. C. T.	do.....	93.3	82.9	94.1	94.9	24.6	88.2
		Average of 2 above.....	95.0	86.2	95.0	96.7	48.2	90.6

TABLE 16.—*Summary of digestion experiments—Digestibility of nutrients and availability of energy of bread alone.*

Ex- peri- ment num- ber.	Subject.	Kind of food.	Coefficients of digestibility.				Availa- bility of energy.
			Total organic matter.	Pro- tein.	Fat.	Carbo- hy- drates.	
			<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
431	P. H. M ...	White bread.....	98.7	94.7	93.5	99.7	94.2
432	J. C. T.	do.....	96.9	91.2	88.5	98.2	91.2
433	W. B. W.	do.....	98.2	95.5	95.9	98.8	93.2
		Average of 3 above	97.9	93.8	92.6	98.9	92.9
434	P. H. M ...	Entire-wheat bread	94.0	81.9	78.6	97.0	88.7
435	J. C. T.	do.....	90.8	78.7	61.6	94.5	83.4
436	W. B. W.	do.....	93.5	81.8	78.4	96.4	88.0
		Average of 3 above.....	92.8	80.8	72.9	96.0	86.7
437	P. H. M ...	Graham bread.....	89.0	81.0	72.1	91.5	83.4
438	J. C. T.	do.....	88.2	81.2	75.1	90.2	81.3
439	W. B. W.	do.....	89.2	81.6	73.7	91.5	83.3
		Average of 3 above	88.8	81.3	73.6	91.1	82.7
440	P. H. M ...	White bread (half ration).....	95.9	85.2	66.9	98.7	90.4
441	J. C. T.	do.....	90.2	77.3	34.5	94.1	79.8
		Average of 2 above	92.7	81.3	50.7	96.4	85.1

It is noticeable that in the experiments with small rations, Nos. 440 and 441, which were like Nos. 431 and 432 in every respect except that the quantity of food was reduced one-half, the digestibility was considerably lower than in those with full rations. The largest difference was in the case of the protein. These results are the opposite of those obtained

by Snyder^a in similar tests. He found that in general the digestibility of the smaller ration was somewhat higher than that of the larger ration of similar food, though the differences were slight.

The results of the experiments here summarized agree in the main with those of the earlier experiments made at this station and those made at the Minnesota Station in this respect, that the nutrients of the white breads were more completely digested than those of the breads from either the entire-wheat or the Graham flour. In the present experiments, however, the average digestibility of the Graham bread was higher than that of the entire-wheat, whereas in the other experiments it was lower. The significance of the results obtained will be best illustrated by applying them to the flours used in these experiments.

The advocates of the coarser flours attach great importance to the fact that these materials contain more total protein than the ordinary white flour. As previously pointed out, the only fair comparison is that between the three grades of flour as milled from the same lot of wheat. From the analyses given in Table 1 it will be seen that for the fresh flours used in this series of experiments the percentage of protein in the entire wheat (No. 6142) was but a trifle higher than that in the white flour (No. 6133), though the difference between these and the Graham flour (No. 6155) was larger. The relations between the protein of the three flours were much the same in the water-free material also, as shown by the following figures:

TABLE 17.—*Percentage of protein in different kinds of flour.*

Kind of flour.	Protein.	
	In fresh flour.	In water-free flour.
	<i>Per cent.</i>	<i>Per cent.</i>
Standard patent	12.75	14.40
Entire-wheat	13.00	14.60
Graham.....	14.00	15.65

The digestibility of the protein of the bread made from these flours was found in these experiments to average, for standard patent, 93.8 per cent; for entire wheat, 80.8 per cent; and for Graham, 81.3 per cent. Multiplying the percentage of total protein in each grade of flour by the coefficient of digestibility here given shows that the three flours in the fresh state contained the following amounts of digestible protein: Standard patent flour, 11.96 per cent; entire-wheat flour, 10.50 per cent; and Graham flour, 11.38 per cent. Thus it appears that the subjects actually obtained more protein from the white flour, which had the lowest proportion of total protein, than from the Graham flour, which had the highest.

^aU. S. Dept. Agr., Office of Experiment Stations Bul. 101.

From such facts as these it is plain that caution should be observed in drawing deductions from analytical data. The results of analyses must be correctly interpreted if the deductions regarding nutritive value drawn from them are to be of any real worth.

DETAILS OF DIGESTION EXPERIMENTS NOS. 442-450.

The experiments of this series were carried out in the spring of 1901, with breads made from standard patent, entire-wheat, and Graham flours, all ground from the same lot of hard spring wheat. This lot of wheat, however, was different from that used in the previous experiments. While the object in the present series was in general the same as in the experiments preceding, a comparison of the digestibility of breads made from different grades of flour ground from the same lot of wheat, the problem was now limited to a determination of the relative rather than the absolute digestibility of the breads under investigation. More specifically, the present experiments were intended to show the relative effects of the three kinds of bread upon the digestibility of a ration more like the ordinary diet than that which was used in the previous experiments. At the same time it was necessary to make up a ration in which the ratio of bread to the other food should remain constant and the kinds and amounts of food other than bread should be always the same. In order that any deduction might be drawn concerning the effect of the different kinds of bread upon the digestibility of the total diet, it was necessary that the proportion of bread be fairly large. The actual amounts of the food materials used were fixed upon by a series of preliminary tests in which the men followed the dictates of their appetites. The individual requirements were found to be so nearly alike that uniform rations could be used for all. While the bread constituted a smaller part of the ration in this series than in experiments Nos. 431-441, about one-half the total protein and energy was derived from it. The diet in the present series was much more varied, beef, chicken, potatoes, and canned peaches being added to the bread, butter, milk, and sugar used in the former tests.

No attempt has been made to estimate the coefficient of digestibility of the bread alone. It has been assumed, in considering these experiments in their bearing on the subject of the nutritive value of different sorts of flour, that any variations due to differences in digestibility of the breads would appear in the values for the digestibility of the whole diet, as the only factor which varied in the different experiments was the character of the flour used to make the bread. The white bread used in this series of experiments was made from the flour represented by sample No. 6443, the entire-wheat bread from flour No. 6444, and the Graham bread from flour No. 6442, described on page 10 of this bulletin.

The following bill of fare for a single day will serve as an illustration of the size and variety of the ration adopted. The menu for each experimental day was made as nearly like this as possible, the amounts of each food material being kept the same each day, with the exception of the bread, the variations in diet thus depending upon the composition rather than quantity of the food eaten. The weights of bread consumed necessarily varied somewhat, since it is impossible to prepare two loaves of equal weight from the same materials, owing to fluctuations in water content. It may be assumed, however, that the three-fourths loaf eaten represented in each case practically the same weight of flour and other solids used in making the bread.

Menu for one day.

Breakfast, 7.15 a. m.:

Bread, three-quarters of a loaf, 559 grams for the day.
Butter, 50 grams for the day.
Potatoes, 120 grams, sliced and fried.
Beef, 50 grams.
Sugar, 50 grams for the day.
Coffee, one cup.
Milk for coffee, 25 grams.

Dinner, 12.15 p. m.:

Bread and butter, as at breakfast.
Beef, 120 grams.
Potatoes, mashed, 150 grams.
Milk used in preparing potatoes, 50 grams.

Supper 5.30 p. m.:

Bread and butter, as at breakfast.
Canned chicken, 75 grams.
Canned peaches, 130 grams.

While each man consumed daily his allotted portion of bread, he was not restricted as to the proportions which should be eaten at each meal. Equal liberty was allowed as regarded the butter. On a few occasions a subject expressed his readiness to add to the menu, but complaints that the amounts supplied were too great were rare. It is very doubtful if any improvement could have been made in these rations for the men under experiment, so far as quantity was concerned.

The subjects of the experiments were three young men. J. E. F., 26 years old, and W. H. E., 20 years old, were university students. E. R. M., 23 years old, was an assistant chemist at the experiment station, who had served as subject in preceding experiments and who by his constant presence and attention to details contributed much to the success of the work.

The following tables, giving the results of the experiments in the the present series, are similar to those on previous pages in so far as they give the results for the total diet, but differ in that they do not show anything concerning the digestibility of the bread alone.

DIGESTION EXPERIMENT NO. 442.

Kind of food.—Mixed diet, including white bread.

Subject.—E. R. M.

Weight (without clothing).—At beginning, 131.4 pounds; at end, 131 pounds.

Duration.—Four days, April 15-18, 1901.

TABLE 18.—*Results of digestion experiment No 442.*

Sample number.		Weight of material.	Total organic matter.	(Protein ($N \times 6.25$).	Fat.	Carbohy- drates.	Ash.	Energy.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
6446	White bread	2,388	1,437.1	232.8	36.8	1,167.5	45.8	6,572
6451	Beef, rib piece	460	193.3	117.0	76.3	.....	16.9	1,361
6452	Chicken	300	123.9	83.0	40.9	.....	6.0	815
6450	Potatoes	1,080	455.3	36.8	1.2	417.3	15.6	1,844
6449	Butter	200	179.2	2.3	176.1	.8	5.5	1,519
6453	Milk	1,200	154.6	42.7	51.4	60.5	8.2	854
	Sugar	83	83.0	-----	-----	83.0	-----	329
	Lard	10	10.0	-----	10.0	-----	-----	93
6454	Peaches	300	45.5	1.7	-----	43.8	.9	160
	Apples	160	24.1	.6	.8	22.7	.5	46
	Total.....	---	2,706.0	516.9	393.5	1,795.6	99.4	13,593
6456	Feces	110.6	97.9	49.0	16.3	32.6	12.7	613
	Amount digested	---	2,608.1	467.9	377.2	1,763.0	86.7	12,980
	Per cent digested	---	96.34	90.52	95.85	98.19	87.22	---
	Estimated energy of urine	---	---	---	---	---	---	385
	Energy of food oxidized in the body	---	---	---	---	---	---	12,595
	Per cent of energy utilized	---	---	---	---	---	---	92.66

During this experiment the subject eliminated 5,504 grams urine containing 56.7 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 20.7 grams; outgo in urine, 14.2 grams, and in feces, 2 grams; making a gain of 4.5 grams nitrogen, corresponding to 28.1 grams protein.

DIGESTION EXPERIMENT NO. 443.

Kind of food.—Mixed diet, including white bread.

Subject.—J. E. F.

Weight (without clothing).—At beginning, 140 pounds; at end, 142.4 pounds.

Duration.—Four days, April 15–18, 1901.

TABLE 19.—*Results of digestion experiment No. 443.*

Sample number.		Weight of material.	Total organic matter.	Protein (N×6.25)	Fat.	Carbohy- drates.	Ash.	Energy.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
6447	White bread	2,420	1,441.4	235.0	38.0	1,168.4	46.0	6,597
6451	Beef, rib piece	460		117.0	76.3		16.9	1,361
6452	Chicken	300		83.0	40.9		6.0	815
6450	Potatoes	1,080	455.3	36.8	1.2	417.3	15.6	1,844
6449	Butter	200	179.2	2.3	176.1	.8	5.5	1,519
6453	Milk	1,200	154.6	42.7	51.4	60.5	8.2	854
	Sugar	83	83.0			83.0		329
	Lard	10	10.0		10.0			93
6454	Peaches	300	45.5	1.7		43.8	.9	160
	Apples	160	24.1	.6	.8	22.7	.5	46
	Total.....			519.1	394.7	1,796.5	99.6	13,618
6457	Feces	86.8		43.3	12.7	18.5	12.3	482
	Amount digested			475.8	382.0	1,778.0	87.3	13,136
	Per cent digested			91.66	96.78	98.97	87.65	
	Estimated energy of urine							367
	Energy of food oxidized in the body.....							12,769
	Per cent of energy utilized							93.76

During this experiment the subject eliminated 3,505 grams urine containing 49.9 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 20.8 grams; outgo in urine, 12.5 grams, and in feces, 1.7 grams; making a gain of 6.6 grams nitrogen, corresponding to 41.3 grams protein.

DIGESTION EXPERIMENT NO. 444.

Kind of food.—Mixed diet, including white bread.

Subject.—W. H. E.

Weight (without clothing).—At beginning, 150.5 pounds; at end, 150.5 pounds.

Duration.—Four days, April 15–18, 1901.

TABLE 20.—Results of digestion experiment No. 444.

Sample number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohy- drates.	Ash.	Energy.
		Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories.
6448	White bread	2,405	1,430.0	232.1	28.7	1,159.2	42.1	6,477
6451	Beef, rib piece	460	.....	117.0	76.3	.....	16.9	1,361
6452	Chicken	300	.....	83.0	40.9	.....	6.0	815
6450	Potatoes	1,080	455.3	36.8	1.2	417.3	15.6	1,844
6449	Butter	200	179.2	2.3	176.1	.8	5.5	1,519
6453	Milk	1,200	154.6	42.7	51.4	60.5	8.2	854
	Sugar	83	83.0	.....	.....	83.0	.....	329
	Lard	10	10.0	.....	10.0	.....	.....	93
6454	Peaches	300	45.5	1.7	.....	43.8	.9	160
	Apples	160	24.1	.6	.8	22.7	.5	46
	Total .....	.....	.....	516.2	395.4	1,787.3	95.7	13,498
6458	Feces	69.3	.....	30.6	12.2	14.2	12.3	482
	Amount digested .....	.....	.....	485.6	383.2	1,773.1	83.4	13,016
	Per cent digested .....	.....	.....	94.07	96.91	99.21	87.15	.....
	Estimated energy of urine .....	.....	.....	.....	.....	.....	.....	413
	Energy of food oxidized in the body .....	.....	.....	.....	.....	.....	.....	12,603
	Per cent of energy utilized .....	.....	.....	.....	.....	.....	.....	93.37

During this experiment the subject eliminated 3,946 grams urine containing 52.3 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 20.6 grams; outgo in urine, 13.1 grams, and in feces, 1.2 grams; making a gain of 6.3 grams nitrogen, corresponding to 39.4 grams protein.

DIGESTION EXPERIMENT NO. 445.

Kind of food.—Mixed diet, including entire-wheat bread.

Subject.—E. R. M.

Weight (without clothing).—At beginning, 132.9 pounds; at end, 132.5 pounds.

Duration.—Four days, April 22–25, 1901.

During this experiment the subject eliminated 4,012 grams urine containing 59.7 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 22.4 grams; outgo in urine, 15 grams, and in feces, 2.2 grams; making a gain of 5.2 grams nitrogen, corresponding to 32.5 grams protein.

DIGESTION EXPERIMENT NO. 447.

Kind of food.—Mixed diet, including entire-wheat bread.

Subject.—W. H. E.

Weight (without clothing).—At beginning, 155.5 pounds; at end, 154 pounds.

Duration.—Four days, April 22-25, 1901.

TABLE 23.—Results of digestion experiment No. 447.

Sample number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohy- drates.	Ash.	Energy.
		Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories.
6473	Entire-wheat bread.....	2,411	1,447.8	233.1	43.4	1,171.3	45.3	6,625
6475	Beef, shoulder clod.....	720	.....	152.4	27.4	.....	16.0	1,107
6476	Chicken.....	300	.....	81.5	37.6	.....	6.8	797
6450	Potatoes.....	1,080	455.3	36.8	1.2	417.3	15.6	1,844
6474	Butter.....	200	174.1	1.9	168.9	3.3	3.8	1,468
6477	Milk.....	1,300	177.2	49.5	55.9	71.8	9.0	1,054
	Sugar.....	83	83.0	.....	.....	83.0	.....	329
	Lard.....	10	10.0	.....	10.0	.....	.....	93
6454	Peaches.....	300	45.5	1.7	.....	43.8	.9	160
	Apples.....	160	24.1	.6	.8	22.7	.5	46
	Total.....	.....	.....	557.5	345.2	1,813.2	97.9	13,523
6480	Feces.....	117.3	.....	48.0	15.0	38.3	16.0	618
	Amount digested.....	.....	.....	509.5	330.2	1,774.9	81.9	12,905
	Per cent digested.....	.....	.....	91.38	95.77	97.89	82.64	.....
	Estimated energy of urine.....	.....	.....	.....	.....	.....	.....	396
	Energy of food oxidized in the body.....	.....	.....	.....	.....	.....	.....	12,509
	Per cent of energy utilized.....	.....	.....	.....	.....	.....	.....	92.50

During this experiment the subject eliminated 4,310 grams urine containing 62.7 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 22.3 grams; outgo in urine, 15.7 grams, and in feces, 1.9 grams; making a gain of 4.7 grams nitrogen, corresponding to 29.4 grams protein.

DIGESTION EXPERIMENT NO. 448.

Kind of food.—Mixed diet, including Graham bread.

Subject.—E. R. M.

Weight (without clothing).—At beginning, 131.8 pounds; at end, 134.4 pounds.

Duration.—April 29 to May 2, four days, 1901.

TABLE 24.—*Results of digestion experiment No. 448.*

Sample number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbo-hydrates.	Ash.	Energy.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
6493	Graham bread	2,480	1,442.9	254.2	53.1	1,136.6	61.8	6,726
6497	Beef, shoulder elod	720		159.4	33.6		21.0	1,191
6498	Chicken	300		82.7	37.6		5.9	811
6450	Potatoes	1,080	455.3	36.8	1.2	417.3	15.6	1,844
6496	Butter	200	177.6	1.8	174.5	1.3	3.3	1,549
6499	Milk	1,200	156.7	44.3	51.6	60.8	8.3	751
	Sugar	83	83.0			83.0		329
	Lard	10	10.0		10.0			93
6454	Peaches	300	45.5	1.7		43.8	.9	160
	Apples	160	24.1	.6	.8	22.7	.5	46
	Total.....			581.5	362.4	1,765.5	117.3	13,500
6500	Feces	193.1		60.6	15.0	90.8	26.7	931
	Amount digested			520.9	347.4	1,674.7	90.6	12,569
	Per cent digested			89.58	95.86	94.86	77.24	
	Estimated energy of urine							425
	Energy of food oxidized in the body							12,144
	Per cent of energy utilized							89.95

During this experiment the subject eliminated 5,417 grams urine containing 66.1 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 23.3 grams; outgo in urine, 16.5 grams, and in feces, 2.4 grams; making a gain of 4.4 grams nitrogen, corresponding to 27.5 grams protein.

DIGESTION EXPERIMENT NO. 449.

Kind of food.—Mixed diet, including Graham bread.

Subject.—J. E. F.

Weight (without clothing).—At beginning, 142.3 pounds; at end, 146 pounds.

Duration.—Four days, April 29 to May 2, 1901.

TABLE 25.—*Results of digestion experiment No. 449.*

[illegible]

During this experiment the subject eliminated 3,214 grams urine containing 47.1 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 23.3 grams; outgo in urine, 11.8 grams, and in feces, 3 grams; making a gain of 8.5 grams nitrogen, corresponding to 53.1 grams protein.

DIGESTION EXPERIMENT NO. 450.

Kind of food.—Mixed diet, including Graham bread.

Subject.—W. H. E.

Weight (without clothing).—At beginning, 156.8 pounds; at end, 155.3 pounds.

Duration.—Four days, April 29 to May 2, 1901.

TABLE 26.—Results of digestion experiment No. 450.

Sample number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohy- drates.	Ash.	Energy.
		Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories.
6495	Graham bread	2,489	1,441.6	250.9	52.0	1,138.7	62.7	6,703
6497	Beef, shoulder clod	720	.....	159.4	33.6	.....	21.0	1,191
6498	Chicken	300	.....	82.7	37.6	.....	5.9	811
6450	Potatoes	1,080	455.3	36.8	1.2	417.3	15.6	1,844
6496	Butter	200	177.6	1.8	174.5	1.3	3.3	1,549
6499	Milk	1,200	156.7	44.3	51.6	60.8	8.3	751
	Sugar	83	83.0	.....	.....	83.0	.....	329
	Lard	10	10.0	.....	10.0	.....	.....	93
6454	Peaches	300	45.5	1.7	.....	43.8	.9	160
	Apples	160	24.1	.6	.8	22.7	.5	46
	Total .....	.....	.....	578.2	361.3	1,767.6	118.2	13,477
6502	Feces	176.3	.....	44.4	15.7	89.8	26.4	829
	Amount digested .....	.....	.....	523.8	345.6	1,677.8	91.8	12,648
	Per cent digested .....	.....	.....	90.59	95.56	94.86	77.67	.....
	Estimated energy of urine .....	.....	.....	.....	.....	.....	.....	431
	Energy of food oxidized in the body .....	.....	.....	.....	.....	.....	.....	12,217
	Per cent of energy utilized .....	.....	.....	.....	.....	.....	.....	90.65

During this experiment the subject eliminated 4,674 grams urine containing 67.5 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 23.1 grams; outgo in urine, 16.9 grams, and in feces, 1.8 grams; making a gain of 4.4 grams nitrogen, corresponding to 27.5 grams protein.

SUMMARY OF RESULTS.

The following table summarizes the results of experiments Nos. 442-450:

TABLE 27.—*Summary of digestion experiments Nos. 442-450—Digestibility of nutrients and energy of total food.*

Experiment number.	Subject.	Kind of food.	Coefficients of digestibility.				Availability of energy.
			Protein.	Fat.	Carbo-hydrates.	Ash.	
			<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
442	E. R. M. ...	White bread and mixed diet...	90.5	95.9	98.2	87.2	92.7
443	J. E. F.	do	91.7	96.8	99.0	87.7	93.8
444	W. H. E.	do	94.1	96.9	99.2	87.2	93.4
		Average of 3 experiments.	92.1	96.5	98.8	87.3	93.3
445	E. R. M. ...	Entire-wheat bread, mixed diet.	91.3	96.9	97.8	83.5	92.9
446	J. E. F.	do	90.0	96.3	97.7	81.2	92.6
447	W. H. E.	do	91.4	95.6	97.9	82.6	92.5
		Average of 3 experiments.	90.9	96.3	97.8	82.4	92.9
448	E. R. M. ...	Graham bread with mixed diet.	89.6	95.9	94.9	77.2	90.0
449	J. E. F.	do	87.1	93.7	94.6	82.0	89.2
450	W. H. E.	do	90.6	95.6	94.9	77.7	90.7
		Average of 3 experiments.	89.1	95.1	94.8	79.0	90.0

As already stated, experiments Nos. 442-450 were intended to show the relative rather than the absolute digestibility of the three kinds of bread, and the coefficients of digestibility are therefore computed for the whole diet, in which the bread was the chief variant. As might be expected, the range of variation in these coefficients is not as great as in experiments Nos. 431-441, in which the quantities of bread eaten formed a larger proportion of the total diet. Nevertheless the results stand in a similar relation to one another, the white-bread ration proving most digestible; in the present series, however, the ration with Graham bread was least digestible, while that with entire-wheat bread occupied rather an intermediate position. It will be noted that the difference between the white and entire-wheat bread rations is less than that between the latter and the Graham bread ration.

DETAILS OF DIGESTION EXPERIMENTS NOS. 451-462.

The present series of experiments, Nos. 451-462, were made with flours ground from soft winter wheat. It was intended that the experiments in this series should be as nearly as possible a repetition of experiments Nos. 442-450, except for the difference in the kinds of wheat from which the flours were ground; but it was found that the Graham flour provided for this series of experiments, probably through some carelessness on the part of the miller, contained a considerable quantity of corn meal. Experiments with the Graham flour were accordingly not made. Later developments also led to some doubt as to the purity of the entire-wheat flours and, though digestion experiments with bread made from them were carried out, the results obtained with these entire-wheat breads should not, therefore, be too strictly compared with those from experiments with bread from entire-wheat flour of known quality.

With these exceptions and the slight differences in the composition of the breads from day to day, the food materials used in this series of digestion experiments were of practically the same character as those used in experiments Nos. 442-450. One of the subjects was an assistant chemist of the experiment station, who took part in the experiments of the previous series; the other two were students who had not before been the subjects of digestion experiments. The results of the experiments are given in the following tables, which require no explanation, since they are like those already given.

DIGESTION EXPERIMENT NO. 451.

Kind of food.—Entire-wheat bread, beef, chicken, potatoes, etc.

Subject.—E. F. B.

Weight (without clothing).—At beginning, 139.5 pounds; at end, 137.5 pounds.

Duration.—Four days, February 17-20, 1902.

TABLE 28.—Results of digestion experiment No. 451.

Sample number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohy- drates.	Ash.	Energy.
		Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories.
6632	Bread, entire-wheat	2,295	1,297.5	169.7	7.8	1,120.0	41.5	5,340
6635	Beef	680	159.7	151.6	8.1	.....	30.8	909
6636	Chicken	300	121.6	83.3	38.3	.....	6.7	808
6637	Potatoes	1,080	263.9	27.5	.4	236.0	10.6	1,095
6638	Butter	200	177.0	1.8	173.4	1.8	4.2	1,478
6639	Peaches	520	74.1	1.6	.....	72.5	2.1	358
	Milk	300	39.6	11.1	12.9	15.6	2.1	215
	Sugar	200	200.0	.....	.....	200.0	.....	792
	Total		2,333.4	446.6	240.9	1,645.9	98.0	10,995
	Feces	97.4	.....	45.6	16.2	22.6	13.0	540
	Amount digested .....		.....	401.0	224.7	1,623.3	85.0	10,455
	Per cent digested .....		.....	87.79	93.28	98.63	86.74	.....
	Estimated energy of urine .....		.....	.....	.....	.....	.....	459
	Energy of food oxidized in the body .....		.....	.....	.....	.....	.....	9,996
	Percent of energy utilized .....		.....	.....	.....	.....	.....	90.91

During this experiment the subject eliminated 5,081 grams urine containing 56.3 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 17.9 grams; outgo in urine, 14.1 grams, and in feces, 1.8 grams; making a gain of 2 grams nitrogen, corresponding to 12.5 grams protein.

DIGESTION EXPERIMENT NO. 452.

Kind of food.—Entire-wheat bread, beef, chicken, potatoes, etc.

Subject.—E. R. M.

Weight (without clothing).—At beginning, 141.5 pounds; at end, 137.8 pounds.

Duration.—Four days, February 17-20, 1902.

During this experiment the subject eliminated 5,304 grams urine containing 59 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 17.7 grams; outgo in urine, 14.7 grams, and in feces, 1.6 grams; making a gain of 1.4 grams nitrogen, corresponding to 8.7 grams protein.

DIGESTION EXPERIMENT NO. 454.

Kind of food.—Blended-flour bread, beef, chicken, potatoes, etc.

Subject.—E. F. B.

Weight (without clothing).—At beginning, 138 pounds; at end, 138 pounds.

Duration.—Four days, February 24–27, 1902.

TABLE 31.—Results of digestion experiment No. 454.

Sample number.		Weight of material.	Total organic matter.	Protein (N × 6.25).	Fat.	Carbohydrates.	Ash.	Energy.
		Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories.
6655	Bread, blended-flour.....	2,262	1,268.9	149.1	10.4	1,109.4	39.4	5,463
6635	Beef	680	159.7	151.6	8.1	.....	30.8	909
6636	Chicken	300	121.6	83.3	38.3	.....	6.7	808
6637	Potatoes	1,080	263.9	27.5	.4	236.0	10.6	1,095
6638	Butter	200	177.0	1.8	173.4	1.8	4.2	1,478
6639	Peaches.....	520	74.1	1.6	.....	72.5	2.1	358
	Milk	300	39.6	11.1	12.9	15.6	2.1	215
	Sugar	200	200.0	.....	.....	200.0	.....	792
	Total .....	.....	2,304.8	426.0	243.5	1,635.3	95.9	11,118
	Feces	86.8	.....	41.4	14.3	19.6	11.5	476
	Amount digested .....	.....	.....	384.6	229.2	1,615.7	84.4	10,642
	Per cent digested .....	.....	.....	90.28	94.13	98.80	88.01	.....
	Estimated energy of urine .....	.....	.....	.....	.....	.....	.....	420
	Energy of food oxidized in the body .....	.....	.....	.....	.....	.....	.....	10,222
	Per cent of energy utilized .....	.....	.....	.....	.....	.....	.....	91.94

During this experiment the subject eliminated 5,014 grams urine containing 46.2 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 17 grams; outgo in urine, 11.5, and in feces, 1.6 grams; making a gain of 3.9 grams nitrogen, corresponding to 24.4 grams protein.

DIGESTION EXPERIMENT NO. 455.

Kind of food.—Blended-flour bread, beef, chicken, potatoes, etc.

Subject.—E. R. M.

Weight (without clothing).—At beginning, 139.8 pounds; at end, 138 pounds.

Duration.—Four days, February 24–27, 1902.

During this experiment the subject eliminated 7,299 grams urine containing 57 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 17.1 grams; outgo in urine, 14.2 grams, and in feces, 1.5 grams; making a gain of 1.4 grams nitrogen, corresponding to 8.7 grams protein.

DIGESTION EXPERIMENT NO. 457.

Kind of food.—Entire-wheat bread, beef, chicken, potatoes, etc.

Subject.—E. F. B.

Weight (without clothing).—At beginning, 136 pounds; at end, 135.5 pounds.

Duration.—Four days, March 3–6, 1902.

TABLE 34.—Results of digestion experiment No. 457.

Sample number.		Weight of material.	Total organic matter.	Protein (N × 6.25).	Fat.	Carbohydrates.	Ash.	Energy.
		Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories.
6673	Bread, entire-wheat	2,326.5	1,268.1	164.2	8.1	1,095.8	45.4	5,443
6676	Beef	680	163.6	151.4	12.2	.....	28.1	945
6677	Chicken	300	120.9	84.7	36.2	.....	6.2	806
6678	Potatoes	1,080	246.3	26.8	.6	218.9	10.5	1,036
6679	Butter	200	176.9	2.2	172.9	1.8	4.2	1,482
6639	Peaches	520	74.1	1.6	.....	72.5	2.1	358
	Milk	300	39.6	11.1	12.9	15.6	2.1	215
	Sugar	200	200.0	.....	.....	200.0	.....	792
	Total		2,289.5	442.0	242.9	1,604.6	98.6	11,077
6680	Feces	70.0	.....	32.5	11.6	16.4	9.5	386
	Amount digested .....		.....	409.5	231.3	1,588.2	89.1	10,691
	Per cent digested .....		.....	92.65	95.23	98.98	90.31	.....
	Estimated energy of urine .....		.....	.....	.....	.....	.....	530
	Energy of food oxidized in the body .....		.....	.....	.....	.....	.....	10,161
	Per cent of energy utilized .....		.....	.....	.....	.....	.....	91.73

During this experiment the subject eliminated 4,801 grams urine containing 48.1 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 17.7 grams; outgo in urine, 12 grams, and in feces, 1.3 grams; making a gain of 4.4 grams nitrogen, corresponding to 27.5 grams protein.

DIGESTION EXPERIMENT NO. 458.

Kind of food.—Entire-wheat bread, beef, chicken, potatoes, etc.

Subject.—E. R. M.

Weight (without clothing).—At beginning, 139 pounds; at end, 136 pounds.

Duration.—Four days, March 3–6, 1902.

During this experiment the subject eliminated 5,984 grams urine containing 46 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 17.4 grams; outgo in urine 11.5 grams, and in feces, 1.6 grams; making a gain of 4.3 grams nitrogen, corresponding to 26.9 grams protein.

DIGESTION EXPERIMENT NO. 460.

Kind of food.—Blended-flour bread, with beef, chicken, potatoes.

Subject.—E. F. B.

Weight (without clothing).—At beginning, 134.5 pounds; at end, 135 pounds.

Duration.—Four days, March 10–13, 1902.

TABLE 37.—Results of digestion experiment No. 460.

Sample number.		Weight of material.	Total organic matter.	Protein (N × 6.25).	Fat.	Carbohy- drates.	Ash.	Energy.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
6695	Bread, blended-flour.....	2,302.5	1,278.1	150.8	6.9	1,120.4	41.2	5,446
6676	Beef	680	163.6	151.4	12.2	.....	28.1	945
6677	Chicken	300	120.9	84.7	36.2	.....	6.2	806
6678	Potatoes	1,080	246.3	26.8	.6	218.9	10.5	1,036
6679	Butter	200	176.9	2.2	172.9	1.8	4.2	1,482
6679	Peaches.....	520	74.1	1.6	.....	72.5	2.1	358
6639	Milk	300	39.6	11.1	12.9	15.6	2.1	215
	Sugar	200	200.0	.....	.....	200.0	.....	792
	Total.....	.....	2,299.5	428.6	241.7	1,629.2	94.4	11,080
6698	Feces	44.7	.....	21.5	7.1	10.0	6.1	247
	Amount digested .....	.....	.....	407.1	234.6	1,619.2	88.3	10,833
	Per cent digested .....	.....	.....	94.98	97.06	99.39	93.54	.....
	Estimated energy of urine .....	.....	.....	.....	.....	.....	.....	526
	Energy of food oxidized in the body .....	.....	.....	.....	.....	.....	.....	10,307
	Per cent of energy utilized .....	.....	.....	.....	.....	.....	.....	93.02

During this experiment the subject eliminated 4,741 grams urine containing 49.2 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 17.1 grams; outgo in urine 12.3 grams, and in feces, 0.8 gram; making a gain of 4 grams, corresponding to 25 grams protein.

DIGESTION EXPERIMENT NO. 461.

Kind of food.—Blended-flour bread, with beef, chicken, potatoes.

Subject.—E. R. M.

Weight (without clothing).—At beginning, 136.3 pounds; at end, 135 pounds.

Duration.—Four days, March 10–13, 1902.

TABLE 38.—Results of digestion experiment No. 461.

Sample number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohy- drates.	Ash.	Energy.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
6696	Bread, blended-flour.....	2,335.5	1,291.9	152.7	7.0	1,132.2	39.9	5,513
6676	Beef	680	163.6	151.4	12.2	.....	28.1	945
6677	Chicken	300	120.9	84.7	36.2	.....	6.2	806
6678	Potatoes	1,080	246.3	26.8	6	218.9	10.5	1,036
6679	Butter	200	176.9	2.2	172.9	1.8	4.2	1,482
6639	Peaches	520	74.1	1.6	.....	72.5	2.1	358
	Milk	300	39.6	11.1	12.9	15.6	2.1	215
	Sugar	200	200.0	.....	.....	200.0	.....	792
	Total.....	.....	2,313.3	430.5	241.8	1,641.0	93.1	11,147
6699	Feces	91.5	.....	49.1	11.1	21.4	9.9	514
	Amount digested.....	.....	.....	381.4	230.7	1,619.6	83.2	10,633
	Per cent digested.....	.....	.....	88.59	95.41	98.70	89.36	.....
	Estimated energy of urine.....	.....	.....	.....	.....	.....	.....	490
	Energy of food oxidized in the body.....	.....	.....	.....	.....	.....	.....	10,143
	Per cent of energy utilized.....	.....	.....	.....	.....	.....	.....	90.99

During this experiment the subject eliminated 5,228 grams urine containing 45.1 grams nitrogen. This makes the nitrogen balance per day as follows: Income in food, 17.2 grams; outgo in urine, 11.3 grams, and in feces, 1.9 grams; making a gain of 4 grams, corresponding to 25 grams protein.

DIGESTION EXPERIMENT NO. 462.

Kind of food.—Blended-flour bread, with beef, chicken, potatoes, etc.
Subject.—E. E. N.

Weight (without clothing).—At beginning, 157.0 pounds; at end, 155.7 pounds.

Duration.—Four days, March 10–13, 1902.

TABLE 39.—Results of digestion experiment No. 462.

Sample number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohy- drates.	Ash.	Energy.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
6697	Bread, blended-flour	2,319	1,289.5	150.7	6.0	1,132.8	40.6	5,582
6676	Beef	680	163.6	151.4	12.2	.....	28.1	945
6677	Chicken	300	120.9	84.7	36.2	.....	6.2	806
6678	Potatoes	1,080	246.3	26.8	6	218.9	10.5	1,036
6679	Butter	200	176.9	2.2	172.9	1.8	4.2	1,482
6639	Peaches	520	74.1	1.6	.....	72.5	2.1	358
	Milk	300	39.6	11.1	12.9	15.6	2.1	215
	Sugar	200	200.0	.....	.....	200.0	.....	792
	Total.....	.....	2,310.9	428.5	240.8	1,641.6	93.8	11,216
6700	Feces	47.7	.....	23.3	7.3	11.3	5.8	266
	Amount digested.....	.....	.....	405.3	233.5	1,630.3	88.0	10,950
	Per cent digested.....	.....	.....	94.58	96.96	99.31	93.81	.....
	Estimated energy of urine.....	.....	.....	.....	.....	.....	.....	642
	Energy of food oxidized in the body.....	.....	.....	.....	.....	.....	.....	10,308
	Per cent of energy utilized.....	.....	.....	.....	.....	.....	.....	91.90

During this experiment the subject eliminated 6,178 grams urine containing 52.4 grams nitrogen. This makes the average nitrogen

balance per day as follows: Income in food, 17.1 grams; outgo in urine, 13.1 grams, and in feces, 0.9 gram; making a gain of 3.1 grams, corresponding to 19.4 grams protein.

SUMMARY OF RESULTS.

The following table summarizes the results of experiments Nos. 451-462:

TABLE 40.—*Summary of experiments Nos. 451-462—Digestibility of nutrients and availability of energy.*

Experiment number.	Subject.	Kind of food.	Coefficients of digestibility.				Availability of energy.
			Protein.	Fat.	Carbo-hydrates.	Ash.	
			<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
451	E. F. B....	Mixed diet, including entire-wheat bread.	89.79	93.28	98.63	86.74	90.91
452	E. R. M....	.....do.....	90.19	95.69	98.69	91.20	91.98
453	E. E. N....	.....do.....	90.83	94.57	98.75	90.54	91.02
		Average of 3 experiments.	90.27	94.51	98.69	89.49	91.30
454	E. F. B....	Mixed diet, including white bread.	90.28	94.13	98.80	88.01	91.94
455	E. R. M....	.....do.....	88.34	95.58	98.61	89.38	93.20
456	E. E. N....	.....do.....	91.03	95.53	99.14	92.45	90.27
		Average of 3 experiments.	89.86	95.08	98.85	89.95	91.80
457	E. F. B....	Mixed diet, including entire-wheat bread.	92.65	95.23	98.98	90.31	91.73
458	E. R. M....	.....do.....	86.55	95.03	98.06	88.35	89.52
459	E. E. N....	.....do.....	90.86	94.62	98.79	89.83	90.52
		Average of 3 experiments.	90.02	94.96	98.61	89.50	90.59
460	E. F. B....	Mixed diet, including white bread.	94.98	97.06	99.39	93.54	93.02
461	E. R. M....	.....do.....	88.59	95.41	98.70	89.36	90.99
462	E. E. N....	.....do.....	94.58	96.96	99.31	93.81	91.90
		Average of 3 experiments.	92.72	96.48	99.13	92.24	91.70

The differences in average digestibility with the two grades of flour were small. No conclusion is warranted from a comparison of the results, however, because as was stated there were reasons for believing that the whole-wheat flours were not what they purported to be. The results summarized in the table above are therefore not discussed.

GENERAL SUMMARY.

The following table summarizes some of the results obtained in experiments carried out at this station to learn the relative digestibility of Graham, whole-wheat, and patent flour bread, including not only the experiments reported in detail in this bulletin but also for purposes of comparison the 24 reported earlier.^a The data here given include

^a U. S. Dept. Agr., Office of Experiment Stations Bul. 85.

the proportion of the total protein and energy of the diet that was supplied by the bread, the coefficients of digestibility of the nutrients of the total diet, and, in the last two columns, the proportion of the total energy that was actually available to the body. These last values are computed in two ways. In the next to the last column the energy lost in the urine is calculated as described on pages 20 and 21, where it is assumed that the average heat of combustion of the organic matter of the urine corresponding to 1 gram of digested protein amounts to 1.25 calories. Since samples of urine were collected in all but the first 24 of these experiments, and the heat of combustion was actually determined in all cases, data are available for calculating the available energy of each experiment on an independent basis, and the results thus obtained are given in the last column.

If this organic matter of the urine were derived entirely from the food under investigation, the results obtained by the second method should, of course, be given the preference. As noted elsewhere (pp. 13 and 56), the "nitrogen lag" makes it impossible to trace any exact relation between the protein of the food eaten on a given day and the nitrogen in the urine. It may be, therefore, that the results obtained by the use of a definite factor, representing the average of a large number of determinations, gives as accurate results as can be obtained at present.

TABLE 41.—Summary of results of digestion experiments with bread—Digestibility of total diet.

Ex- peri- ment- num- ber.	Date.	Subject.	Kind of food.	Duration of experi- ment.	Propor- tion of total pro- tein sup- plied by bread.	Propor- tion of total en- ergy sup- plied by bread.	Digestibility of nutrients.				Availability of en- ergy of food when energy of urine was—			
							Total or- ganic matter.	Protein.	Fat.	Carbohy- drates.	Ash.	Calcu- lated.		Deter- mined.
												Per cent.	Per cent.	
123	1896	H. B. S.	White bread.	2	100	96.8	90.9	82.3	98.3	43.9	92.7	Per cent.		
124	1896	H. B. S.	do.	2	100	95.5	80.0	65.6	98.9	54.3	91.2	.....	
125	1896	L. H. H.	do.	2	100	94.6	81.7	67.5	97.7	32.6	90.3	.....	
126	1896	J. W. F.	do.	2	100	94.7	75.4	67.2	98.7	67.1	90.7	.....	
127	1897	L. H. H.	White bread and milk	2	63	95.2	86.5	83.6	98.0	78.8	94.1	.....	
128	1897	H. B. S.	do.	2	57	96.8	90.8	92.8	97.7	70.1	91.5	.....	
129	1897	C. W. S.	do.	2	62	96.5	91.9	94.2	97.9	61.7	91.6	.....	
130	1897	P. F. F.	do.	2	49	94.9	89.2	86.4	97.8	56.1	89.5	.....	
131	1897	C. W. S.	Graham bread and milk	2	50	92.6	88.7	94.4	93.7	68.0	88.6	.....	
132	1897	F. H. M.	do.	2	55	94.3	88.7	94.1	94.5	64.1	89.2	.....	
133	1897	C. D. H.	do.	2	41	92.3	91.9	96.7	94.4	70.6	90.4	.....	
134	1897	P. F. F.	do.	2	39	94.5	87.2	93.3	93.3	54.0	88.5	.....	
135	1897	C. W. S.	Entire-wheat bread and milk	2	52	94.6	89.1	93.2	96.5	69.0	90.1	.....	
136	1897	P. F. F.	do.	2	47	97.0	93.6	97.2	97.9	74.8	92.5	.....	
137	1897	A. B. O.	do.	2	45	96.2	92.7	96.1	97.2	72.5	91.7	.....	
138	1897	A. J. P.	White bread and milk	2	51	98.3	96.3	91.4	94.6	84.0	94.6	.....	
139	1897	B. R. M.	do.	2	46	97.8	95.4	98.1	98.1	76.3	92.3	.....	
140	1897	A. J. P.	do.	2	44	97.7	95.4	98.3	98.1	80.0	93.1	.....	
141	1897	O. W. K.	do.	2	42	96.8	90.4	97.5	97.5	78.3	93.2	.....	
142	1897	A. J. P.	Entire-wheat bread and milk	2	61	97.4	93.5	98.0	98.0	81.9	93.7	.....	
143	1897	O. W. K.	do.	2	59	93.6	87.8	96.6	93.8	63.2	90.2	.....	
144	1897	A. J. P.	Graham bread and milk	2	58	94.1	87.7	97.5	94.3	70.1	91.1	.....	
145	1897	O. W. K.	do.	2	50	98.6	97.8	99.0	98.7	85.6	95.0	.....	
146	1897	O. W. K.	White bread and milk	2	46	98.6	95.9	98.3	99.4	88.5	95.0	.....	
431	1899	P. H. M.	White bread, milk, butter, and sugar	2	65	97.5	93.2	98.0	98.2	75.4	94.1	.....	
432	1899	J. C. T.	do.	2	70	98.3	96.4	98.7	98.6	84.1	94.7	.....	
433	1899	W. B. W.	do.	2	63	97.5	86.0	95.8	97.1	74.4	91.9	.....	
434	1899	P. H. M.	Entire-wheat bread, milk, butter, and sugar	2	48	95.4	83.2	95.6	95.2	55.9	90.7	.....	
435	1899	J. C. T.	do.	2	77	95.2	85.7	96.6	96.6	75.3	90.3	.....	
436	1899	W. B. W.	do.	2	55	95.2	86.7	95.2	92.7	61.9	89.2	.....	
437	1899	P. H. M.	Graham bread, milk, butter, and sugar	2	66	92.4	85.6	97.0	92.5	49.8	90.0	.....	
438	1899	J. C. T.	do.	2	74	92.7	85.6	95.8	92.5	58.9	88.7	.....	
439	1899	W. B. W.	do.	2	45	92.4	85.5	95.8	92.5	58.9	88.7	.....	
440	1899	P. H. M.	White bread, milk, butter, and sugar	2	56	96.8	89.5	93.9	98.6	71.8	93.0	.....	
441	1899	J. C. T.	do.	2	52	93.3	82.9	94.1	94.9	24.6	88.2	.....	

TABLE 41.—Summary of results of digestion experiments with bread—Digestibility of total diet—Continued.

Ex-periment num-ber.	Date.	Subject.	Kind of food.	Duration of ex-periment.	Proportion of total protein sup-plied by bread.		Proportion of total en-ergy sup-plied by bread.		Digestibility of nutrients.				Availability of en-ergy of food when was—	
					Days.	Per cent.	Per cent.	Total or-ganic matter.	Protein.	Fat.	Carbohy-drates.	Ash.	Calcu-lated.	Deter-mined.
442	1901	E. R. M.	White bread, mixed diet.....	4	45	48	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
443	1901	J. E. F.	do.....	4	45	48	.....	.....	.....	.....	.....	.....	.....	.....
444	1901	W. H. E.	do.....	4	45	48	.....	.....	.....	.....	.....	.....	.....	.....
445	1901	E. R. M.	Entire-wheat bread, mixed diet.....	4	42	48	.....	.....	.....	.....	.....	.....	.....	.....
446	1901	J. E. F.	do.....	4	42	49	.....	.....	.....	.....	.....	.....	.....	.....
447	1901	W. H. E.	do.....	4	42	49	.....	.....	.....	.....	.....	.....	.....	.....
448	1901	E. R. M.	Graham bread, mixed diet.....	4	44	50	.....	.....	.....	.....	.....	.....	.....	.....
449	1901	J. E. F.	do.....	4	44	50	.....	.....	.....	.....	.....	.....	.....	.....
450	1901	W. H. E.	do.....	4	43	50	.....	.....	.....	.....	.....	.....	.....	.....
451	1902	E. F. B.	Entire-wheat bread, mixed diet.....	4	38	49	.....	.....	.....	.....	.....	.....	.....	.....
452	1902	E. R. M.	do.....	4	38	50	.....	.....	.....	.....	.....	.....	.....	.....
453	1902	E. E. N.	do.....	4	38	50	.....	.....	.....	.....	.....	.....	.....	.....
454	1902	E. F. B.	White bread, mixed diet.....	4	35	49	.....	.....	.....	.....	.....	.....	.....	.....
455	1902	E. R. M.	do.....	4	35	49	.....	.....	.....	.....	.....	.....	.....	.....
456	1902	E. E. N.	do.....	4	35	49	.....	.....	.....	.....	.....	.....	.....	.....
457	1902	E. F. B.	Entire-wheat bread, mixed diet.....	4	37	49	.....	.....	.....	.....	.....	.....	.....	.....
458	1902	E. R. M.	do.....	4	38	50	.....	.....	.....	.....	.....	.....	.....	.....
459	1902	E. E. N.	do.....	4	36	49	.....	.....	.....	.....	.....	.....	.....	.....
460	1902	E. F. B.	White bread, mixed diet.....	4	35	49	.....	.....	.....	.....	.....	.....	.....	.....
461	1902	E. R. M.	do.....	4	35	49	.....	.....	.....	.....	.....	.....	.....	.....
462	1902	E. E. N.	do.....	4	35	50	.....	.....	.....	.....	.....	.....	.....	.....

Some interesting deductions may be drawn from the data summarized in Table 41. It is evident that, in general, the nutrients of bread when eaten alone were not as completely digested as when the bread was eaten with milk. It is also noticeable that the coefficients of digestibility of the nutrients of a more varied diet, including large proportions of bread, were not greater on the average than those obtained with a simple ration of bread and milk.

In general, the digestibility of the ration, whether simply bread and milk with a little butter and sugar or a more varied diet, was decreased when the change was made from white bread to entire-wheat bread, and still further decreased when either was replaced by Graham bread, the remainder of the diet being, of course, the same in all three cases. The differences are sufficient to indicate that, even though the Graham flour contains the most and the white flour the least total protein of the three, the body would obtain more protein and energy from a pound of entire wheat than from a pound of Graham flour, and still more from a pound of white flour than from either of the others.

On the other hand, it does not follow from this that a larger amount of digestible nutrients or available energy may not be obtained from 100 pounds of wheat when milled as Graham flour or entire-wheat flour than when ground into patent flour, because 100 pounds of cleaned and screened wheat will yield 100 pounds of Graham flour, about 85 pounds of entire-wheat flour, and only a little over 72 pounds of standard patent flour. This, however, is a question of pecuniary economy, which would be more appropriately discussed elsewhere.

From all the data included in this bulletin and in others reporting previous work on the same subject, it is evident that all kinds of wheat bread are quite well digested and worthy of the important place in the diet which they hold. In fact, there is no single food which is so indispensable as bread. It is a very economical source of nutriment, and the different kinds are valuable as affording means for variety in the diet.

INCOME AND OUTGO OF NITROGEN.

The following table summarizes the data regarding the income of nitrogen in the food, the outgo in the feces and urine, and the gain or loss by the body in the digestion experiments with different kinds of bread reported on preceding pages. The figures in each case represent the total quantities for an experiment.

TABLE 42.—*Income and outgo of nitrogen in digestion experiments Nos. 431-462.*

Ex- peri- ment num- ber.	Subject.	Kind of food.	Dura- tion.	Nitrogen.			
				In food.	In urine.	In feces.	Gain (+) or loss (-).
			Days.	Grams.	Grams.	Grams.	Grams.
431	P. H. M. . . .	White bread, with milk, butter, and sugar.	2	36.4	35.1	1.5	+ 0.2
432	J. C. T.	do	2	22.7	19.4	1.5	+ 1.8
433	W. B. W.	do	2	24.5	26.9	0.9	- 3.3
434	P. H. M.	Entire-wheat bread, milk, butter, and sugar.	2	32.0	27.7	4.5	- 0.2
435	J. C. T.	do	2	21.4	18.6	3.6	+ 0.2
436	W. B. W.	do	2	19.6	23.6	2.8	- 6.8
437	P. H. M.	Graham bread, milk, butter, and sugar.	2	37.3	30.8	5.0	+ 1.5
438	J. C. T.	do	2	20.5	18.1	3.0	- 0.6
439	W. B. W.	do	2	21.7	24.1	3.2	- 5.6
440	P. H. M.	White bread, milk, butter, and sugar.	2	17.0	23.1	1.8	- 7.9
441	J. C. T.	do	2	10.7	18.0	1.8	- 9.1
442	E. R. M.	Mixed diet, including white bread.	4	82.70	55.66	7.85	+19.19
443	J. E. F.	do	4	83.06	49.88	6.93	+26.25
444	W. H. E.	do	4	82.59	52.52	4.89	+25.18
445	E. R. M.	Mixed diet, including entire- wheat bread.	4	89.71	60.78	7.81	+21.12
446	J. E. F.	do	4	89.60	59.74	8.92	+20.96
447	W. H. E.	do	4	89.20	62.74	7.68	+18.78
448	E. R. M.	Mixed diet, including Graham bread.	4	93.04	66.14	9.69	+17.21
449	J. E. F.	do	4	93.31	47.14	11.99	+34.18
450	W. H. E.	do	4	92.51	67.49	7.10	+17.92
451	E. F. B.	Mixed diet, including entire- wheat bread.	4	71.5	56.3	7.3	+ 7.9
452	E. R. M.	do	4	71.3	47.0	7.0	+17.3
453	E. E. N.	do	4	71.0	59.0	6.5	+ 5.5
454	E. F. B.	Mixed diet, including white bread.	4	68.2	46.2	6.6	+15.4
455	E. R. M.	do	4	68.6	-----	8.0	-----
456	E. E. N.	do	4	68.3	57.0	6.1	+ 5.2
457	E. F. B.	Mixed diet, including entire- wheat bread.	4	70.7	48.1	5.2	+17.4
458	E. R. M.	do	4	71.5	40.7	9.6	+21.2
459	E. E. N.	do	4	69.7	46.0	6.4	+17.3
460	E. F. B.	Mixed diet, including white bread.	4	68.6	49.2	3.4	+16.0
461	E. R. M.	do	4	68.9	45.1	7.8	+16.0
462	E. E. N.	do	4	68.6	52.4	3.7	+12.5

In the experiments in which the diet consisted almost wholly of bread and milk there was in all but a few cases only a small difference between the nitrogen in the food consumed and that in the excretory products. In the experiments with mixed diet, on the other hand, in all but four cases the differences were larger. It is noticeable, too, that in the former experiments there was in some cases a gain and in others a loss of nitrogen, but in the latter there was a gain of nitrogen in every case. It will be observed that the income of nitrogen was much larger in all the experiments with mixed diet than in those with the more simple diet. Since nothing was known concerning the conditions of income and outgo of nitrogen with the subjects preceding the experimental periods, it is impossible to tell just in how far the nitrogen of the urine collected during the experiments represents that of the food consumed, because of uncertainty regarding the lag of excretion of nitrogen pertaining to the food previous to that of the experiments. Late investigations carried on by P. B. Hawk^a

^aAmer. Jour. Physiol., 10 (1903), p. 115.

indicate that an increase of nitrogen in the food is eliminated in the urine in a comparatively short time. It may perhaps be fair to assume that at least in the experiments with mixed diet, which were of longer duration than the others, there was some relation between the nitrogen of the food and that of the urine. That being the case, the results would indicate that the diet in these experiments, which contained large proportions of bread, was more than sufficient to meet the bodily needs of the subjects for protein, so that in each instance there was a storage of protein. This was true whether the diet contained white, entire-wheat, or Graham bread, no differences being observed that could be attributed to different sorts of bread.

METABOLIC PRODUCTS IN FECES.

It has been noted that in harmony with the general custom the digestibility in these experiments was determined in accordance with the assumption that the feces consist entirely of undigested residue. It is well known, however, that they contain, in addition to such material, considerable amounts of various waste substances—the so-called metabolic products—consisting of residues from the bile, mucus, saliva, gastric juice, pancreatic juice, and other digestive secretions, small portions of the mucous membrane lining the intestine, débris from the walls of the stomach, etc. The results of recent investigations indicate that the proportion of metabolic products in the feces is larger than was formerly supposed, and that for many foods, provided there has been careful preparation and proper mastication, digestion is quite complete, the undigested residues in the feces being accidental rather than incidental. Much study is now being given to this subject, and attempts are made by chemical and microscopical methods to determine the amounts of metabolic products excreted daily in the feces, inasmuch as such data are necessary before estimates of the actual digestibility of food materials can be made. In a former bulletin reporting experiments at the Maine Station some of the more important investigations were mentioned.

In general it may be said that of the several chemical methods thus far proposed for separating the undigested material from the other products the following have seemed most promising, namely, one in which the attempt is made to dissolve the metabolic products of the feces by pepsin or other ferments, leaving the undigested residue of the food, and the other, in which the attempt is made to dissolve out the metabolic products by treatment with one or more solvents, likewise leaving the undigested residue behind.

In view of the importance of such work, studies of the amounts of metabolic nitrogen in the feces have been carried on as a part of the investigation of the nutritive values of bread at the Maine Experiment Station, and the results of such studies made in connection with the

digestion experiments reported in this bulletin are reported in the following pages, but simply as a contribution to the knowledge of the subject, without any extended discussion. The methods employed in these studies were (1) treatment of the feces with pepsin solution, and (2) treatment with ether, alcohol, hot water, and cold limewater.

TREATMENT OF FECES WITH PEPSIN.

As in earlier experiments at the Maine Experiment Station^a a weighed portion of the finely ground feces from each digestion experiment was treated according to the usual method with a pepsin solution prepared by dissolving 1.25 grams of German plain soluble pepsin in 1 liter of 0.2 per cent hydrochloric acid (made by adding 20 cubic centimeters of a solution containing exactly 10 per cent hydrochloric-acid gas to 1 liter of water) and adding 5 cubic centimeters of a solution of thymol in alcohol as a preservative. Two hundred cubic centimeters of this solution was heated to 50° C., the weighed quantity of feces was then added, and the beaker kept in a water bath at 40° C. for eight hours on two successive days. At intervals of two hours 1 cubic centimeter of 10 per cent hydrochloric acid was added until the final strength of the solution was 0.5 per cent. On the day following the second period of digestion on the water bath the solution was decanted upon folded filters. The residue was washed by decantation and also upon the filter until no test for proteids was obtained in the wash water. The filter and contents were then dried, as much as possible of the top of the filter was cut off, and the nitrogen in the dried material, which was assumed to represent the nitrogen of undigested material, was determined by the Kjeldahl method, a suitable correction being made in the results for the small amount of nitrogen of the filter paper. The results obtained by this method are shown in Table 43.

TREATMENT OF FECES WITH ETHER, ALCOHOL, HOT WATER, AND LIMEWATER.

The treatment of feces by this method, which was the same in these experiments as in those previously reported was, in brief, as follows: One gram of finely ground feces was boiled for one-half hour with 25 cubic centimeters of anhydrous ether in a small flask with a reversed condenser, the ether decanted upon a filter, and the operation repeated. After washing with ether by decantation, 50 cubic centimeters of 95 per cent alcohol was poured upon the residue of the feces in the flask and boiled for ten minutes, a reversed condenser being used as before. The alcohol was decanted upon the same filter as was used for the ether

^aU. S. Dept. Agr., Office of Experiment Stations Bul. 85.

extract and the whole washed with hot alcohol. The sample of feces was then heated on a steam bath for twenty minutes with 50 cubic centimeters of water and the whole washed with hot water upon the same filter as before. Feces and filter were then placed in a beaker with 50 cubic centimeters of a saturated solution of limewater and allowed to stand for six hours, after which the whole was thoroughly washed upon a fresh filter with dilute limewater. The residue was then dried and the nitrogen in it determined by the Kjeldahl method, a correction being applied for the nitrogen in the filters. The results of experiments by this method of making correction for the metabolic nitrogen of feces in the digestion experiments are also shown in Table 43.

The significance of the figures included in the table may be explained by use of the data from one of the experiments, for instance No. 431. In one method the nitrogen of metabolic products was assumed to be dissolved out of the feces by pepsin solution, leaving the undigested protein in the feces not dissolved. During the two days of this experiment the total feces, partially dried, weighed 27.8 grams and contained 5.39 per cent or 1.50 grams of nitrogen. The portion of the feces not dissolved by treatment with pepsin contained 1.25 per cent of nitrogen, which would give 0.35 gram in the total feces as coming from undigested protein. Subtracting the latter from the total nitrogen of the food (which was estimated as 16 per cent of the total protein) would give $(36.37 - 0.35 =) 36.02$ grams as digestible nitrogen, implying that 99.04 per cent of the total nitrogen was digested. Obviously, this would also be the coefficient of digestibility of protein of the food as corrected for metabolic products determined by this method.

In the other method the metabolic products were likewise assumed to be dissolved by treatment with the several solvents, leaving the undigested protein in the material not dissolved. Considering again the figures for experiment No. 431, it will be observed that the residue from feces not dissolved by this method contained 3.32 per cent or 0.92 gram of nitrogen, which, subtracted from the total in the food, gave 35.45 grams as the amount digested, the coefficient of digestibility being in this case 97.47 per cent.

In those experiments in which the diet consisted of bread, butter, milk, and sugar, namely, Nos. 431-441, corresponding values for the digestibility of the nitrogen from the bread alone were computed by proportion. As previously explained (p. 19), the protein in the feces due to undigested bread was calculated by assuming a factor for the digestibility of the protein in the rest of the diet; and the nitrogen in it was calculated in the usual way by assuming that the protein contained 16 per cent of this element. In order to calculate the quantity

of metabolic nitrogen of the feces that would be due to bread alone, it was assumed that the nitrogen in the total feces bears the same relation to the nitrogen in the feces from bread alone that the nitrogen not dissolved by treatment in the total feces bears to the nitrogen not dissolved in the feces from bread alone. Thus, in experiment No. 431, the nitrogen not dissolved by treatment with pepsin in the feces from bread was 0.29 gram as computed according to the following proportion: $1.50 : 0.35 :: 1.25 : 0.29$. In the same way the nitrogen in the feces from bread not dissolved by treatment with ether, alcohol, hot water, and limewater was 0.77 gram as computed according to the proportion $1.50 : 0.92 :: 1.25 : 0.77$.

This is equivalent to the assumption that the metabolic products from the digestion of milk and other foods besides bread would constitute the same proportion of the total feces as those from the digestion of bread itself. Although there is no definite warrant for this assumption, it seems fair to say the results can be but slightly affected by considerable variations in the relative amounts, owing to the fact that the quantity of nitrogen in the feces from foods other than bread was generally considerably smaller than that from bread.

Table 43 summarizes the figures showing the digestibility of nitrogen (protein) when corrections for metabolic nitrogen in the feces are introduced.

TABLE 43.—Coefficients of digestibility of nitrogen (protein) of food when allowance is made for nitrogen of metabolic products in feces.

Kind of food.	Nitrogen in food.	Weight of water-free feces.		Total nitrogen in feces.		Feces treated with pepsin.			Feces treated with ether, alcohol, hot water, and lime-water.		
		Grams.	Per cent. a	Grams.	Per cent. a	Nitrogen in feces not dissolved.	Corrected digestibility of nitrogen of food.	Grams.	Nitrogen in feces not dissolved.	Corrected digestibility of nitrogen of food.	Per cent.
Experiment No. 431—White bread, milk, butter, and sugar:											
Entire diet.....	36.37	27.8	5.39	1.50	1.25	0.35	36.02	99.04	3.32	0.92	35.45
Bread alone.....	23.63			1.25		.29	23.34	98.76		.77	22.86
Experiment No. 432—White bread, milk, butter, and sugar:											
Entire diet.....	22.72	36.8	4.19	1.54	1.06	.39	22.33	98.29	2.96	1.09	21.63
Bread alone.....	16.02			1.41		.36	15.66	97.77		1.00	15.02
Experiment No. 433—White bread, milk, butter, and sugar:											
Entire diet.....	24.48	23.4	3.75	.88	1.12	.26	24.22	98.95	2.95	.69	23.79
Bread alone.....	15.54			.70		.21	15.33	98.65		.55	14.39
Experiment No. 434—Entire-wheat bread, milk, butter, and sugar:											
Entire diet.....	31.84	86.2	5.15	4.44	1.38	1.19	30.65	96.26	3.29	2.81	29.00
Bread alone.....	23.73			4.29		1.15	22.58	95.15		2.74	20.99
Experiment No. 435—Entire-wheat bread, milk, butter, and sugar:											
Entire diet.....	21.39	92.0	3.89	3.58	1.04	.96	20.43	95.50	2.31	2.13	19.26
Bread alone.....	16.37			3.49		.94	15.43	94.25		2.07	14.30
Experiment No. 436—Entire-wheat bread, milk, butter, and sugar:											
Entire diet.....	19.55	57.6	4.83	2.78	1.40	.81	18.74	95.86	3.19	1.84	17.71
Bread alone.....	14.75			2.69		.78	13.97	94.75		1.78	12.97
Experiment No. 437—Graham bread, milk, butter, and sugar:											
Entire diet.....	37.33	148.4	3.35	4.97	.82	1.22	36.11	96.75	2.11	3.13	34.20
Bread alone.....	24.82			4.72		1.16	23.66	95.80		2.97	21.85
Experiment No. 438—Graham bread, milk, butter, and sugar:											
Entire diet.....	20.50	102.2	2.90	2.96	.88	.90	19.60	95.60	2.14	2.19	18.31
Bread alone.....	15.17			2.85		.87	14.30	94.25		2.11	13.06
Experiment No. 439—Graham bread, milk, butter, and sugar:											
Entire diet.....	21.68	97.6	3.24	3.16	1.15	1.12	20.56	94.85	2.32	2.26	19.42
Bread alone.....	16.58			3.06		1.08	15.50	93.48		2.19	14.39
Experiment No. 440—White bread, milk, butter, and sugar:											
Entire diet.....	17.02	32.6	5.48	1.79	1.50	.49	16.53	97.15	3.88	1.26	15.76
Bread alone.....	11.31			1.68		.46	10.85	95.95		1.18	10.13
Experiment No. 441—White bread, milk, butter, and sugar:											
Entire diet.....	10.67	49.6	3.68	1.83	1.14	.57	10.10	94.65	2.80	1.39	9.28
Bread alone.....	7.74			1.76		.54	7.20	93.02		1.34	6.40

a Per cent of weight of water-free feces.

TABLE 43.—*Coefficients of digestibility of nitrogen (protein) of food when allowance is made for nitrogen of metabolic products in feces—Continued.*

Kind of food.	Nitrogen in food.	Weight of water in feces.	Total nitrogen in feces.		Feces treated with pepsin.				Feces treated with ether, alcohol, hot water, and lime-water.	
					Nitrogen in feces not dissolved.		Corrected diges- tibility of nitrogen of food.	Nitrogen in feces not dissolved.		Corrected diges- tibility of nitrogen of food.
					Per cent.	Grams.		Per cent.	Grams.	Per cent.
Experiment No. 412—Mixed diet, including white bread.....	82.70	119.8	6.55	7.85	2.27	79.98	96.71	3.94	4.72	77.98
Experiment No. 413—Mixed diet, including white bread.....	83.06	95.2	7.28	6.93	2.53	80.65	97.10	4.28	4.07	78.99
Experiment No. 441—Mixed diet, including white bread.....	82.59	73.0	6.70	4.89	2.54	80.74	97.74	4.18	3.05	79.54
Experiment No. 445—Mixed diet, including entire-wheat bread.....	89.71	126.8	6.16	7.81	2.36	86.72	96.66	4.08	5.17	81.54
Experiment No. 446—Mixed diet, including entire-wheat bread.....	89.60	141.6	6.30	8.92	2.33	86.30	96.32	4.40	6.23	83.37
Experiment No. 447—Mixed diet, including entire-wheat bread.....	89.20	129.4	5.93	7.68	1.74	86.95	97.47	4.00	5.18	84.02
Experiment No. 448—Mixed diet, including Graham bread.....	93.04	208.0	4.66	3.69	3.11	86.57	93.04	3.25	6.76	86.28
Experiment No. 449—Mixed diet, including Graham bread.....	93.30	243.8	4.88	12.00	3.25	85.31	91.44	2.93	7.20	86.10
Experiment No. 450—Mixed diet, including Graham bread.....	92.51	192.0	3.70	7.10	2.49	87.73	94.84	2.57	4.93	87.58
Experiment No. 451—Mixed diet, including entire-wheat bread.....	71.46	111.4	6.55	7.30	2.28	68.92	96.44	4.22	4.70	67.26
Experiment No. 452—Mixed diet, including entire-wheat bread.....	71.31	97.0	7.21	6.99	2.25	69.13	96.94	4.75	4.61	66.70
Experiment No. 453—Mixed diet, including entire-wheat bread.....	71.04	95.6	6.81	6.51	2.17	68.97	97.09	4.46	4.26	66.78
Experiment No. 454—Mixed diet, including white bread.....	68.16	97.3	6.80	6.62	2.91	65.23	95.17	4.66	4.53	66.63
Experiment No. 455—Mixed diet, including white bread.....	68.58	105.0	7.62	8.00	2.66	65.79	95.94	4.28	4.49	64.09
Experiment No. 456—Mixed diet, including white bread.....	68.29	80.8	7.58	6.12	2.54	66.24	97.00	4.95	4.00	61.29
Experiment No. 457—Mixed diet, including entire-wheat bread.....	70.72	80.8	6.43	5.20	2.20	68.94	97.48	3.97	3.21	67.51
Experiment No. 458—Mixed diet, including entire-wheat bread.....	71.47	129.4	7.43	9.61	2.45	68.30	95.56	4.96	6.42	65.05
Experiment No. 459—Mixed diet, including entire-wheat bread.....	69.70	94.0	6.77	6.36	2.25	67.58	96.96	4.48	4.21	65.49
Experiment No. 460—Mixed diet, including white bread.....	68.57	50.7	6.79	3.44	2.51	67.30	98.15	4.56	2.31	66.26
Experiment No. 461—Mixed diet, including white bread.....	68.89	103.6	7.58	7.85	2.62	66.28	96.21	5.07	5.25	63.64
Experiment No. 462—Mixed diet, including white bread.....	68.56	53.6	6.92	3.71	2.43	67.26	98.10	4.67	2.50	66.06

The results included in the above table are made use of elsewhere (p. 65) in discussing the true digestibility of the different sorts of bread studied. In general it may be said that, as shown by these experiments, a considerable part of the nitrogen in the feces was due to metabolic products rather than undigested residue, or, in other words, that the protein of the ration was quite thoroughly digested.

ARTIFICIAL DIGESTION OF BREAD WITH PEPSIN.

A report of earlier experiments^a carried on in the laboratory of the Maine Experiment Station contained an account of tests of the digestibility of the protein of bread made from different grades of flour by means of pepsin solution, in which was included a brief discussion of the Stutzer method for carrying on such work and the various modifications of this method which have been proposed from time to time. It is of course the purpose in artificial digestion experiments to approximate as closely as possible the conditions of heat, moisture, and ferment activity found in the animal body, but it is safe to say that the results obtained as yet in the laboratory are generally regarded as of more importance relatively than absolutely. That is, such experiments are better fitted to show differences in the ease, the rapidity, or the thoroughness of digestion in a given time of two or more materials treated in exactly similar ways than to indicate what would be the result when they were eaten, or the actual amount of nutrients which the same materials would supply to the body in their passage through the digestive tract.

The tests reported in the following pages are similar in every way to the earlier work carried on in this laboratory, which was referred to above. Briefly, the method employed consisted of mixing 1 gram of finely ground "partially dry" bread with 200 cubic centimeters of pepsin solution prepared by dissolving 1.25 grams of German plain pepsin in 1 liter of 0.2 per cent hydrochloric acid. The pepsin solution containing the bread was kept on a water bath at 50-60° C. for eight hours on two consecutive days, fresh hydrochloric acid being added every two hours. After standing over the night following the second day of heating, the clear supernatant liquid was decanted and the remainder filtered. The undissolved, that is, undigested, residue was dried, weighed, and its nitrogen content determined as usual. Deducting this amount of nitrogen from the amount originally present in the bread gave the amount digested under the experimental conditions. The following table gives the results obtained when samples of breads made from entire-wheat, Graham, and white flours ground from the same lot of wheat were digested with pepsin

^a U. S. Dept. Agr., Office of Experiment Stations Bul. 85.

solution, the breads used being the same as in digestion experiments with men, Nos. 431-462:

TABLE 44.—*Results of experiments on digestion of breads of different sorts with pepsin solution.*

Sample number.	Kind of bread.	Nitrogen.			
		In bread.	In undigested portion.	In digested portion.	Coefficients of digestibility.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
6131	White bread.....	2.16	0.06	2.10	97.22
6132	.....do.....	2.10	.12	1.98	94.29
	Average of 2 above.....	2.13	.09	2.04	95.76
6143	Entire-wheat bread.....	2.17	.13	2.04	94.01
6144	.....do.....	2.19	.09	2.10	95.89
6145	.....do.....	2.04	.07	1.97	96.56
	Average of 3 above.....	2.13	.10	2.04	95.49
6156	Graham bread.....	2.19	.10	2.09	95.43
6157	.....do.....	2.22	.13	2.09	94.14
	Average of 2 above.....	2.20	.11	2.09	94.79
6195	White bread.....	1.99	.09	1.90	95.49
6196	.....do.....	1.99	.03	1.96	98.49
	Average of 2 above.....	1.99	.06	1.93	96.99
6446	White bread.....	2.31	.05	2.26	97.84
6447	.....do.....	2.32	.04	2.28	98.27
6448	.....do.....	2.32	.06	2.26	97.41
	Average of 3 above.....	2.32	.05	2.27	97.84
6471	Entire-wheat bread.....	2.36	.07	2.29	97.03
6472	.....do.....	2.32	.08	2.24	95.00
6473	.....do.....	2.30	.07	2.23	96.96
	Average of 3 above.....	2.33	.07	2.26	97.00
6493	Graham bread.....	2.49	.18	2.31	92.77
6494	.....do.....	2.49	.14	2.35	94.38
6495	.....do.....	2.46	.12	2.34	95.12
	Average of 3 above.....	2.48	.15	2.33	94.09
6632	Entire-wheat bread.....	1.86	.03	1.83	98.39
6633	.....do.....	1.82	.05	1.77	97.25
6634	.....do.....	1.83	.03	1.80	98.36
6673	.....do.....	1.84	.04	1.80	97.83
6674	.....do.....	1.85	.05	1.80	97.30
6675	.....do.....	1.83	.05	1.78	97.26
	Average of 6 above.....	1.84	.04	1.80	97.73
6655	White bread.....	1.67	.05	1.62	97.00
6656	.....do.....	1.70	.04	1.66	97.65
6657	.....do.....	1.67	.04	1.63	97.59
6695	.....do.....	1.70	.06	1.64	96.47
6696	.....do.....	1.71	.05	1.66	97.08
6697	.....do.....	1.69	.05	1.64	97.04
	Average of 6 above.....	1.69	.05	1.64	97.14

From the figures in the above table it will be seen that the protein of bread made from straight patent, entire-wheat, or Graham flour was quite thoroughly digested by the pepsin. The differences observed between the different sorts of bread were not great, yet on the whole it is evident that the protein of the Graham bread was somewhat less completely digested than that of the white or the entire-wheat bread.

As regards the two sorts last mentioned the differences noted are very small, although the advantage is with the white bread. These deductions hold good whether the average results of all the tests are considered or whether the results of individual pairs of tests are compared.

COMPARISON OF COEFFICIENTS OF DIGESTIBILITY OF PROTEIN IN BREAD AS DETERMINED BY DIFFERENT METHODS.

Table 45 summarizes the coefficients of digestibility of the nitrogen (or protein) of breads made from different grades of flour, as shown by the results of both natural and artificial digestion experiments, including in the former case the results as actually determined and as corrected for the nitrogen of metabolic products in the feces. As explained above, the feces were treated in two ways, with a ferment and with various solvents, to remove the metabolic products, and the nitrogen in the undissolved portion was considered in each case as pertaining to undigested residues of food. The table includes only the results for breads used in experiments Nos. 431-441, since these were the only ones of those here studied in which it was possible to estimate the digestibility of the protein of bread alone.

TABLE 45.—*Digestibility of nitrogen (or protein) of different kinds of bread as determined by different methods.*

Sample number.	Kind of bread.	Artificial digestion.	Natural digestion.	Natural digestion with correction obtained by pepsin method.	Natural digestion with correction obtained by ether, alcohol, hot water, and limewater method.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
6131	White bread.....	95.72	94.71	98.76	96.74
6132					
6131		95.68	91.25	97.77	93.76
6132					
6131		94.95	95.49	98.65	96.48
6132					
	Average of 3.....	95.45	93.82	98.39	95.66
6143	Entire-wheat bread.....	96.35	81.94	95.15	88.45
6144					
6143		95.58	78.72	94.25	87.35
6144					
6143		95.67	81.78	94.75	87.93
6144					
6145		95.87	80.81	94.72	87.91
	Average of 3.....				
6156	Graham bread.....	94.78	80.95	95.30	88.04
6157					
6156		94.86	81.19	94.25	86.09
6157					
6156		95.75	81.60	93.48	86.79
6157					
	Average of 3.....	95.13	81.25	94.34	86.97
6195	White bread.....	97.05	85.16	95.95	89.55
6196					
6195		96.97	77.21	93.02	82.69
6196					
	Average of 2.....	97.01	81.19	94.49	86.12

As will be seen from a comparison of the data in the table, the largest coefficients for the white bread were those from the natural digestion experiments as corrected for the nitrogen of metabolic products in the feces. With the other breads the results from the artificial experiments were highest, while those from the natural digestion experiments without the corrections were the lowest. In the artificial digestion experiments the pepsin solution used seemed to act with almost equal readiness upon the protein of all three kinds of bread, whereas in the experiments with men the protein of the white bread was more completely digested than that of either of the other kinds. These facts favor the idea often held that the apparently incomplete digestion of the coarse breads is due in part to their more rapid passage through the digestive tract. In the artificial digestion there is of course no such acceleration, the period of digestion being the same in all cases.

INVESTIGATION OF METHODS FOR SEPARATION OF FECES.

The success of a digestion experiment, unless it be of longer duration than is usually found practicable, must depend very largely upon the accuracy of the separation of the feces. Unless the experimenter is able to distinguish with tolerable exactness between the feces from the food under investigation and feces from food taken immediately before and after the experiment, his work is of little value. In some experiments, particularly those of the earlier investigators, the assumption was made that the feces of a given day pertain to the food of the preceding day. Doubtless for healthy men of regular habits the period which elapses before the undigested portion of any given diet is excreted agrees in a general way with such an assumption, but the method is too indefinite for accurate experiments. The method which has given most satisfactory results consists in imparting to the feces a particular color, or consistency, or both, to distinguish them from the feces of the preceding and following diets. It has been found that a diet consisting largely or wholly of milk produces feces of a well-marked and individual character as regards general color and consistency. Grape juice, blueberry juice, and similar materials impart a distinct color to the feces. Charcoal and lampblack, which also give a distinct color to the feces, differ from vegetable coloring matters in that they are not affected by the digestive juices, but are excreted unchanged. Grape seeds, berry seeds, bits of string, etc., may be readily detected in the feces, and at times have been used as markers.

Many investigators have reported data regarding the value of one or more methods of marking and separating feces. The literature of the subject has been studied in connection with the experiments herewith, but no attempt is made to summarize the data here, as it is

believed that such a summary would be more appropriate when further investigations similar to those here reported have been carried out.

Experience has shown that with the best means yet tried it is often difficult and sometimes impossible to make satisfactory separations of the feces. Methods that have been used successfully with one subject may prove failures with another or with the same subject at another time.

The essentials of a good marker are as follows: (1) It must be of such a character that it can be unerringly detected in the feces. (2) It must be such that it will not to any appreciable extent disturb the secretion of the digestive juices or the regular action of the intestines; i. e., it must be neither constipating nor laxative in its effect. (3) It must not lag, but must move uniformly with the residues of the food with which it was ingested. (4) It should not diffuse.

The markers most commonly employed are of three general classes: (1) Foods producing feces of distinctive character, such as milk, grapes, grape juice, blueberries, etc. (2) Solid matter, not digestible, that will pass unchanged through the digestive tract, imparting a color, as lampblack, or which may be easily discovered, as knotted strings. (3) Composite markers, combining two or more of the above characteristics, as milk and lampblack.

Of the various markers that have been employed at this station, milk accompanied by lampblack in many instances has proved satisfactory. Since milk feces are scanty, consisting perhaps more of metabolic products than of undigested matter, for the best results the milk should be given in large quantities unmixed with other food. The resulting feces from such a meal are very smooth, pasty, and tenacious, and when well localized are very satisfactory as a marker. In the earlier digestion experiments at this station very good results were thus obtained; but in some of the later work both milk feces and marker were found so incorporated with the feces from the preceding and the following food that it was thought advisable to try other methods. An objection to the use of milk was found in the undesirable constipating effect it frequently produces. In several trials lampblack given with the ordinary food proved as satisfactory as when used with milk alone.

Grapes and raisins were found unreliable, the seeds sometimes preceding and sometimes lagging far behind the feces they were supposed to accompany. Grape juice was tried with two subjects, and in one case its laxative effect was so pronounced as to preclude its use as a marker. With the other subject the effect was equally decided but of quite the opposite character, the subject, although previously regular at stool, becoming very constipated.

Some of the more striking results obtained up to the present time (1903) are given here. Many other experiments of a similar nature have been made, with results in harmony with and confirming those mentioned.

LAMPBLACK AS A MARKER.

Much of the difficulty encountered in attempts to mark feces with lampblack has been due to the wide distribution of the color through the feces, which is undoubtedly effected by the muscular contractions of the stomach and intestines.

A very convenient method of administering the lampblack and one which has been generally followed in the nutrition investigations of which the present series forms a part, is to inclose it in gelatin capsules about 0.75 inch long and 0.3 inch in diameter. Since these capsules are readily soluble in water, they are doubtless ruptured in a short time after they enter the stomach, and it was thought that diffusion might be largely prevented by delaying as long as possible the perforation or solution of the capsule and the consequent liberation of the lampblack.

To test this, ten tests were made with two subjects, E, a student, and M, a chemist, both healthy young men, the marker in each case being a gelatin capsule filled with lampblack, taken in seven tests with a meal of either milk or eggs alone, and in three with ordinary mixed diet. In the first four experiments the capsules were untreated, but in the other six they were doubly coated with shellac, which it was believed would render them less easily soluble and hinder the liberation of the lampblack. The feces were deposited on tin trays which were slowly moved along so as to secure the feces in a straight line, thus facilitating the examination of them. The results of the tests were as follows:

TABLE 46.—*Results of tests with lampblack as a marker for feces.*

	Marked meal.	Nature of meal.	Distribution of lampblack.	Separation by means of color.
CAPSULE UNTREATED.				
Experiment No. 1, subject E...	Supper	Milk....	Very widely diffused.....	Difficult.
Experiment No. 2, subject E...	.....do.....	.....do.....	Widely diffused.....	Impossible.
Experiment No. 3, subject M...	.....do.....	Eggs....	Somewhat diffused.....	Moderately good.
Experiment No. 4, subject M...	.....do.....	.....do...	Localized.....	Do.
CAPSULE DOUBLY COATED WITH SHELLAC.				
Experiment No. 5, subject M..	Supper	Mixed..	Somewhat diffused.....	Fair.
Experiment No. 6, subject E...	.....do.....	Milk....	Localized, but in streaks.	Difficult.
Experiment No. 7, subject E...	Breakfast.	.....do.....	Localized.	Fair.
Experiment No. 8, subject E...	.....do.....	.....do.....	Localized in streaks.....	Poor.
Experiment No. 9, subject M...	.....do.....	Mixed..	Localized in nodules.....	Perfect.
Experiment No. 10, subject M...	.....do.....	.....do...	.....do.....	Do.

With the subject E the milk supper had little if any effect in securing a more decided separation of the feces, since the milk feces were in each case more or less intimately mixed with the adjacent feces from other foods. With the subject M the marked meal consisted of eggs or was made up of a number of foods, and the separations were more satisfactory.

It was noted repeatedly that the lampblack used as a marker, together with more or less of the feces colored by it, lagged behind; that is,

fecal matter pertaining to food of a later meal preceded it in excretion. In many cases the color was found well localized in the feces, but the colored portion lay on one side of the center, as though that part of the feces had adhered to one side of the intestines while the undigested remnants of later food had been pushed by. In later experiments such a condition was apparently avoided, but with no gain in accuracy of separation, by the use of larger amounts of lampblack, which resulted in a wider diffusion of the color. Somewhat similar cases of lagging were noted in which several segments of the feces were thoroughly blackened on the exterior while within they were normal in color, and this when the main body of the blackened feces had passed by. In such cases there seemed to have been a telescoping of the intestinal contents, the central portions being forced through and beyond the outer ones.

Where diffusion of the lampblack occurred it was usually observed that the first limit of the blackened feces was much more sharply defined than the last. In the later work, therefore, the method of separation by means of a prefatory and supplementary meal of milk accompanied by a capsule of lampblack, which, as previously stated, was followed in the earlier investigations of this Department, was abandoned, and the lampblack was given with the regular breakfast of the first day of the experiment proper and with the breakfast of the day following the last one of the experiment. In making the separations of the feces, that blackened by the first lampblack was retained as belonging to the experiment, while that colored by the lampblack given after the close of the experiment was discarded. This is in harmony with the results of tests reported by Sherman in a recent bulletin,^a in which lampblack was taken with the breakfast of experiments succeeding one another without interruption, rather than with the supper preceding, since, as stated by Sherman, "It is very much easier to determine the point which marks the first appearance of the feces from a meal with which lampblack has been taken than to decide exactly where the feces from such a meal end; apparently because, as would be expected, enough lampblack may sometimes adhere to the walls of the intestines to give more or less color to the feces from meals subsequent to that with which it was taken."

ACTION OF PEPSIN UPON TREATED GELATIN CAPSULES.

Several methods were tried for retarding the solution of the gelatin capsules in the stomach. Mention has already been made of coating them with shellac. The effect of this procedure, and of treating the capsules with tannin and with formaldehyde, was studied by noting the action of pepsin solution upon capsules thus treated. A

^a U. S. Dept. Agr., Office of Experiment Stations Bul. 121.

number of capsules were filled with quartz sand and powdered cochineal—the former to increase the specific gravity and secure more complete submergence of the capsule in the digestive fluid, and the latter to communicate its color to the solution and thus indicate the perforation of the capsule.

In these tests 10 capsules were used, as follows: Nos. 1 and 2 were given a single coating of shellac; Nos. 3 and 4 were doubly coated with shellac; Nos. 5 and 6 were immersed two minutes in a strong solution of tannin and then dried; Nos. 7 and 8 were not treated, and Nos. 9 and 10 were kept five minutes in a 20 per cent solution of formaldehyde and then dried. Each of these capsules except No. 8 was placed in a separate beaker containing 100 cubic centimeters of pepsin solution prepared as described above, that had been previously warmed to 40° C., and was maintained at that temperature until the liquid was colored by the cochineal. As a control test No. 8 was kept in pure water at the same temperature.

Capsules Nos. 1 and 2, which had the single coating of shellac, were ruptured or perforated in 30 minutes, so that the cochineal colored the liquid; Nos. 3 and 4, with the double coating of shellac, in 70 minutes; No. 5, treated with tannin, in 7 minutes 30 seconds; No. 6, also treated with tannin, in 5 minutes; No. 7, not treated, in 3 minutes; and No. 8, the duplicate of No. 7, which was kept in warm water, also in 3 minutes. Nos. 9 and 10, which had been treated with formaldehyde, showed the greatest resistance to the action of the pepsin. After 4 hours of continuous digestion, although the gelatin had become much softened, a mere trace of the cochineal had passed into the solution; and while after 2 hours' further digestion the color had deepened greatly, the capsules still retained their form. From what has been observed in our experiments with men it seems certain that in the alimentary canal all of these capsules would have been ruptured in less time than in these tests with pepsin solution.

Coating the capsule with shellac, as shown by the tests, retarded the solution of the gelatin, and in the tests with men it decreased the tendency toward a diffusion of the charcoal. It can not be inferred from this, however, that the coated capsules would give more accurate results in digestion experiments with men than the uncoated. On the contrary, there is reason to believe that a capsule before disintegration is more subject to displacement than are its contents when thoroughly incorporated with the feces.

KNOTTED STRINGS AS MARKERS.

Two experiments, extending through several weeks, were made with knotted strings as markers for feces. A loosely twisted, soft, white cotton string, such as is used for tying small parcels, was chosen for the purpose, in the belief that it would prove less irritating to the

intestine than hard twine. With each meal a piece about 1.5 inches long was swallowed. Generally, in the string taken with breakfast, one knot was tied, two in that with dinner, and three in that with supper; but from time to time, in order that the strings of one day might not be mistaken for those of another, a departure was made from this rule, four knots being used to indicate breakfast and two and three knots at varying distances to mark the other meals. The diet was simple but generous. The subject was a man whose duties required considerable activity. He defecated once nearly every day during the experiments, taking care that the feces were deposited in such a way that the order of the discharge of the strings could be accurately determined.

The results of the experiments are shown in the following table, which gives the meals taken, the time of discharge of the feces, the order of ingestion of the strings, the order of their discharge, and the length of the period between ingestion and discharge:

TABLE 47.—*Relative movement of string markers in their passage through the alimentary canal.*

Date of ingestion.	Order of ingestion.	Time of defecation.	Number and order of strings in the feces.	Period between ingestion and discharge.
FIRST SERIES.				<i>Hours.</i>
Saturday, April 28:		Saturday, April 28, ^a		
Morning	1			
Noon	2			
Night	3			
Sunday, April 29:		Sunday, April 29:		
Morning	4			
Noon	5	9 a. m.	{ 1	26
Night	6		{ 2	21
Monday, April 30:		Monday, April 30:		
Morning	7		{ 3	42
Noon	8	Noon	{ 5	24
Night	9		{ 4	29
Tuesday, May 1:		Tuesday, May 1:		
Morning	10		{ 6	46
Noon	11	4 p. m.	{ 8	28
Night	12		{ 7	33
Wednesday, May 2:		Wednesday, May 2:		
Morning	13		{ 9	42
Noon	14	Noon	{ 10	24
Night	15		{ 12	18
			{ 11	24
Thursday, May 3:		Thursday, May 3:		
Morning	16		{ 13	32
Noon	17	3 p. m.	{ 15	21
Night	18			
Friday, May 4:		Friday, May 4:		
Morning	19		{ 14	52
Noon	20	4 p. m.	{ 16-17	33-28
Night	21		{ 18	22
Saturday, May 5:		Saturday, May 5:		
Morning	22		{ 19	33
Noon	23	4 p. m.	{ 21	22
Night	24		{ 20	28
Sunday, May 6:		Sunday, May 6:		
Morning	25		{ 22	33
Noon	26	4 p. m.	{ 23	28
Night	27			
Monday, May 7:		Monday, May 7:		
Morning	28		{ 27	23
Noon	29		{ 25	34
Night	30	5 p. m.	{ 28	10
			{ 24	47
			{ 26	29

^a Feces from experiment did not appear.

TABLE 47.—*Relative movement of string markers in their passage through the alimentary canal*—Continued.

Date of ingestion.	Order of ingestion.	Time of defecation.	Number and order of strings in the feces.	Period between ingestion and discharge. Hours.
FIRST SERIES—continued.				
Tuesday, May 8:		Tuesday, May 8:		
Morning	31	No feces.		
Noon	32			
Night	33			
Wednesday, May 9:		Wednesday, May 9:		
Morning	34		29	49
Noon	35	1 p. m.	30	43
Night	36		32	25
			31-33	30-19
Thursday, May 10:		Thursday, May 10:		
Morning	37	Noon	34-35	29-24
Noon	38			
Night	39			
Friday, May 11:		Friday, May 11:		
Morning	40		36	45
Noon	41	3 p. m.	37	32
Night	42		38	27
Saturday, May 12:		Saturday, May 12:		
Morning	43		40	33
Noon	44	4 p. m.	41	28
Night	45		39	46
Sunday, May 13:		Sunday, May 13:		
Morning	a 46		43	27
Noon	a 47	10 p. m.	42	40
Night	a 48		44	44
			45	16
SECOND SERIES.				
Tuesday, May 15:		Tuesday, May 15. ^b		
Morning	1			
Noon	2			
Night	3			
Wednesday, May 16:		Wednesday, May 16:		
Morning	4		1	29
Noon	5	Noon	2	24
Night	6		3	18
Thursday, May 17:		Thursday, May 17:		
Morning	7		5	28
Noon	8	4 p. m.	4	33
Night	9		6	22
Friday, May 18:		Friday, May 18:		
Morning	10	No feces.		
Noon	11			
Night	12			
Saturday, May 19:		Saturday, May 19:		
Morning	13		8	48
Noon	14		7	53
Night	15	Noon	10	29
			11	24
			9	42
			12	18
Sunday, May 20:		Sunday, May 20:		
Morning	16		14	24
Noon	17	Noon	13	29
Night	18		15	18
Monday, May 21:		Monday, May 21:		
Morning	19	No feces.		
Noon	20			
Night	21			
Tuesday, May 22:		Tuesday, May 22:		
Morning	22		16	53
Noon	23		17	48
Night	24	Noon	20	24
			18	42
			21	18
			19	29
Wednesday, May 23:		Wednesday, May 23:		
Morning	25	No feces.		
Noon	26			
Night	27			
Thursday, May 24:		Thursday, May 24:		
Morning	28		24	46
Noon	29	4 p. m.	23	52
Night	30		22	57
			25	33

^a Feces containing these strings not collected.^b Feces from experiment did not appear.

TABLE 47.—*Relative movement of string markers in their passage through the alimentary canal*—Continued.

Date of ingestion.	Order of ingestion.	Time of defection.	Number and order of strings in the feces.	Period between ingestion and discharge.
SECOND SERIES—continued.				<i>Hours.</i>
Friday, May 25:		Friday, May 25:		
Morning	31	11 a. m.	26	47
Noon	22		27	41
Night	33		29	23
			30	17
			28	28
Saturday, May 26:		Saturday, May 26:		
Morning	34	1 p. m.	33	19
Noon	35		31	30
Night	36			
Sunday, May 27:		Sunday, May 27:		
Morning	37	3 p. m.	32	51
Noon	38		34	32
Night	39		35	27
			36	21
Monday, May 28:		Monday, May 28:		
Morning	40	1 p. m.	37	30
Noon	41		38	25
Night	42			
Tuesday, May 29:		Tuesday, May 29:		
Morning	43	4 p. m.	39	46
Noon	44		40	33
Night	45			
Wednesday, May 30:		Wednesday, May 30:		
Morning	46	1 p. m.	41	49
Noon	47		42	43
Night	48		44	25
			43	30
			45	19
Thursday, May 31:		Thursday, May 31:		
Morning	49	5 p. m.	46	34
Noon	50		47	29
Night	51			
Friday, June 1:		Friday, June 1:		
Morning	52	3 p. m.	48	45
Noon	53		49	32
Night	54			
Saturday, June 2:		Saturday, June 2:		
Morning	55	3 p. m.	51	45
Noon	56		50	51
Night	57		54	21
			52	32
			53	27
Sunday, June 3:		Sunday, June 3:		
Morning	58	5 p. m.	55	34
Noon	59			
Night	60			
Monday, June 4:		Monday, June 4:		
Morning	(a)	Noon	57	42
Noon	(a)		56	48
Night	(a)		60	18
			59	24
			58	29

(a) No strings taken.

The first experiment as a whole covered 16 days, the data in the table above showing the order of ingestion and discharge of 45 strings. The time which elapsed between the ingestion and the appearance of a string in the feces varied in different instances from 10 to 52 hours, the average being about 29 hours. In only five tests did the markers appear in the feces in the same order as that in which they were taken with the food. In seven cases there was a simple transposition; that is, the string from one meal appeared before that of the meal next following. For instance, in the feces on April 30 the string taken with dinner on April 29 preceded that taken with breakfast on

the same day. More complex transpositions occurred on May 7 and 12. Marker No. 24, which appeared on the former date, was not discharged until 47 hours after its ingestion, and was preceded by three strings taken with later meals, one of which, No. 28, required only 10 hours from ingestion to discharge. In several cases, as with strings Nos. 16 and 17, two markers were so located in the feces that neither could be given priority.

The number of markers appearing at each discharge of feces varied from 2 to 5. The discharge on May 9 was the first for two days, and the extra number was to be expected. Likewise, of the five markers discharged May 7, one had lagged from May 5. But why No. 28 should have appeared 10 hours after ingestion is not clear, since the feces were apparently perfectly normal, though they were retained until a later hour than usual. The subject had been engaged during the afternoon in rather hard work.

The second experiment continued for a longer period—21 days, on the last of which no strings were given. The results were perhaps even more striking than those just noted. While the markers were given regularly, in only eight tests did they appear in the feces in the same order as that in which they were taken. In twelve instances the string given with one meal appeared before that of the meal immediately preceding; and twice, namely, on May 22 and June 4, the order of the discharge of the strings for three succeeding meals was the reverse of that of their ingestion, the one given with breakfast being discharged last and that with supper of the same day appearing first. The period of longest retention was 57 hours, but on five other occasions the period exceeded 50 hours. The shortest period was 17 hours, and the average for the 60 markers was a little over 33 hours.

Considering the two experiments as a whole 108 markers were used, 35 of which, or about one-third of the total number, in the passage through the alimentary canal overtook and passed markers that had been taken before them. Only 44 strings, or 40 per cent of the total number, accomplished the passage and were excreted in the order in which they were taken.

In all probability all the strings left the stomach and entered the intestines in the order in which they were ingested. In that case the transposition took place in the intestines; whether in the small or large intestine or in the rectum immediately before expulsion is immaterial so far as concerns the present discussion.

Although the subject of these experiments was a strong, healthy man, it may be that after all the conditions were not strictly normal, since the kind of work he performed may have had some influence upon the results. It is quite conceivable that retention of the feces beyond the regular time of discharge might result in a more complete mixing of the intestinal contents. Nevertheless the work shows the

unreliability of string markers, and to a greater or less degree of markers in general. All matter evidently does not pass through the intestines in the order in which the food is ingested.

In some of the most pronounced cases of lagging the strings were found in the feces in positions that indicated that they must have been in contact with the walls of the intestine, so that their forward movement was retarded by friction. This is similar to the phenomenon that was repeatedly observed in experiments in which lampblack was used, as noted on page 68.

That the intestinal walls are able to change the position at least of irritating bodies is shown by the results of experiments carried on by A. Exner^a with dogs and cats fed pieces of glass and pins inclosed in gelatin capsules. It was found that the position of the objects was quite generally changed in their passage through the intestinal tract so that the sharp points did not come in contact with the intestinal walls. In proof of this it was noted that by far the larger number of pins were excreted head first, whether they were swallowed in this way or not.

It is quite probable that the displacement of the knotted strings in the experiments carried on at the Maine Station was accidental, as it hardly seems probable that the knots would prove irritating enough to the intestinal walls to cause a change in position of the same character as that observed by Exner, but until more evidence is available it can not be said with certainty that the susceptibility of the intestinal walls to irritating substances was not a factor in the change of position of the knotted strings.

SUMMARY OF EXPERIMENTS WITH MARKERS.

None of the markers thus far tried have fully met the conditions previously noted as essential.

Solid markers, like strings and grape or fig seeds, although possessing the virtue of easy detection in the feces, are subject to considerable displacement, and may be found far from the portion of the feces that they were intended to mark. Finely divided, insoluble matter, such as lampblack, though less likely to be displaced than the coarse material, frequently becomes so diffused as to be useless as a marker, the color passing by imperceptible gradations into the normal. Methods which prevent diffusion of color do not necessarily insure accuracy of separation.

The first appearance of a color marker is more sharply defined than the last.

Foods, such as milk or Graham bread, which produce characteristic feces, may also fail, through diffusion, to insure an accurate separation.

^a Arch. Physiol. [Pflüger], 89 (1902), p. 253.

While many of these markers may give, and in many cases have given, satisfactory results, the percentage of failures is large.

Markers which prove satisfactory with one subject may fail with another, or with the same subject in another experiment.

In digestion experiments reliable results can be hoped for only when the experimental period is fairly long, at least four days, and the subjects are of regular habits. Regularity is a matter of the greatest importance, since feces can rarely be so marked that separations can safely be made by color alone. Increased accuracy may be obtained when evacuations take place daily and at about the same hour. Retention of the intestinal contents beyond the usual period appears often to result in greater displacement of different portions of the feces than would otherwise be likely.

While too great reliance should not be placed on a marker of any kind, as shown by the results of a large number of experiments, lampblack, when properly used, has given tolerably good results, and may be considered a valuable aid in the separation of feces. The texture of the feces and the time of their appearance (if the subject be of regular habits) are factors which must be considered of equally great importance.

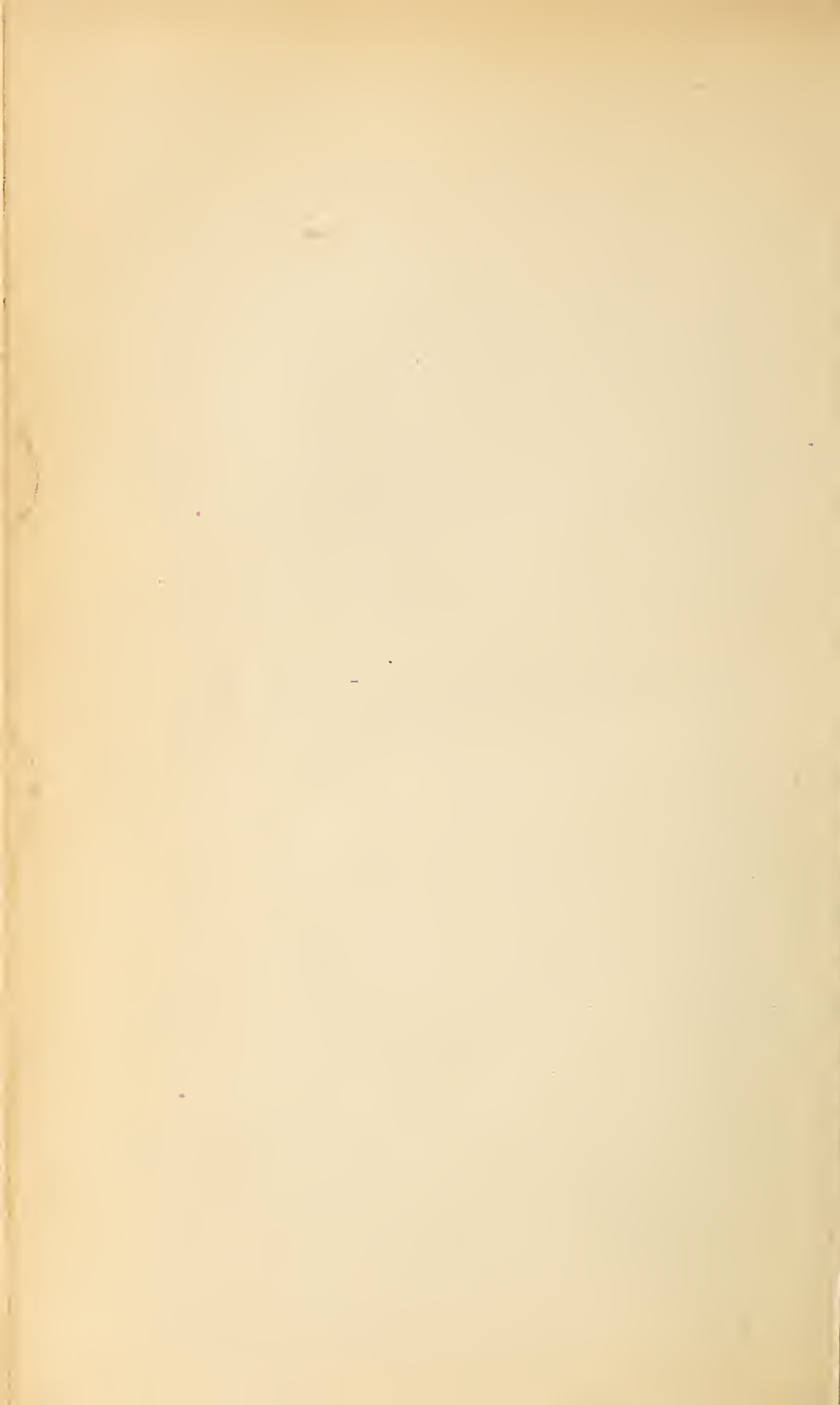
METHOD ADOPTED FOR DIGESTION EXPERIMENTS WITH MEN.

As a result of the studies with markers which have been reported and the experience gained in previous experiments, the following method for digestion experiments with men has been adopted in the work at this station:

Digestion experiments are made for periods of not less than four days. When conditions permit, the supper preceding the first meal of the experiment consists of food yielding feces of a texture different from that of feces from the food used in the experiment. A single untreated gelatin capsule filled with lampblack is taken with the breakfast of the first day, and a similar capsule with the breakfast of the day following the last one of the experiment, this meal, like the one preceding the experiment, being preferably of food different from that used in the experiment. If the color is well localized the separation is usually easy, the first lot of colored feces being included in that reserved for analysis, while the colored feces pertaining to the breakfast following the last meal are rejected. The texture of the feces is also carefully noted. If, as sometimes happens, a portion of the feces thus collected appears to have been mixed with that from other foods, the different parts are mechanically separated according to the general appearance of the feces, and the portion not pertaining to the diet studied is rejected. An examination of the feces outside the limits defined by the markers sometimes shows small amounts from

the food under investigation which must also be mechanically separated and included with that for analysis. Such mechanical separation of the different parts of the feces may be readily made with a spatula, and when done under a hood with a good draft need not be especially disagreeable.

Special pains are taken to impress upon the subject the importance of the utmost regularity, particularly as to the time of evacuation. The subject is also cautioned against a too radical change of diet after the experimental period is ended. Too free indulgence in fruits at the close of the experiment and before the appearance of the second marker is particularly to be avoided, since the laxative effect of such food may render a satisfactory final separation impossible. A four-day experiment may be made worthless by failure to observe a few simple precautions of this kind. It must be remembered that the experiment is not finished and vigilance should not be relaxed until the second marker has appeared and the final separation is made.



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